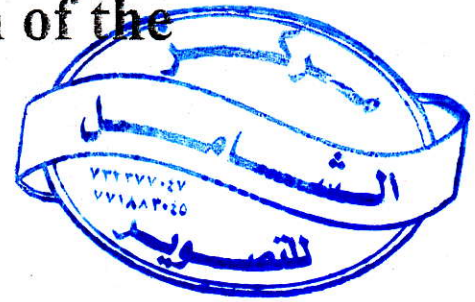


Physiology of the nervous system

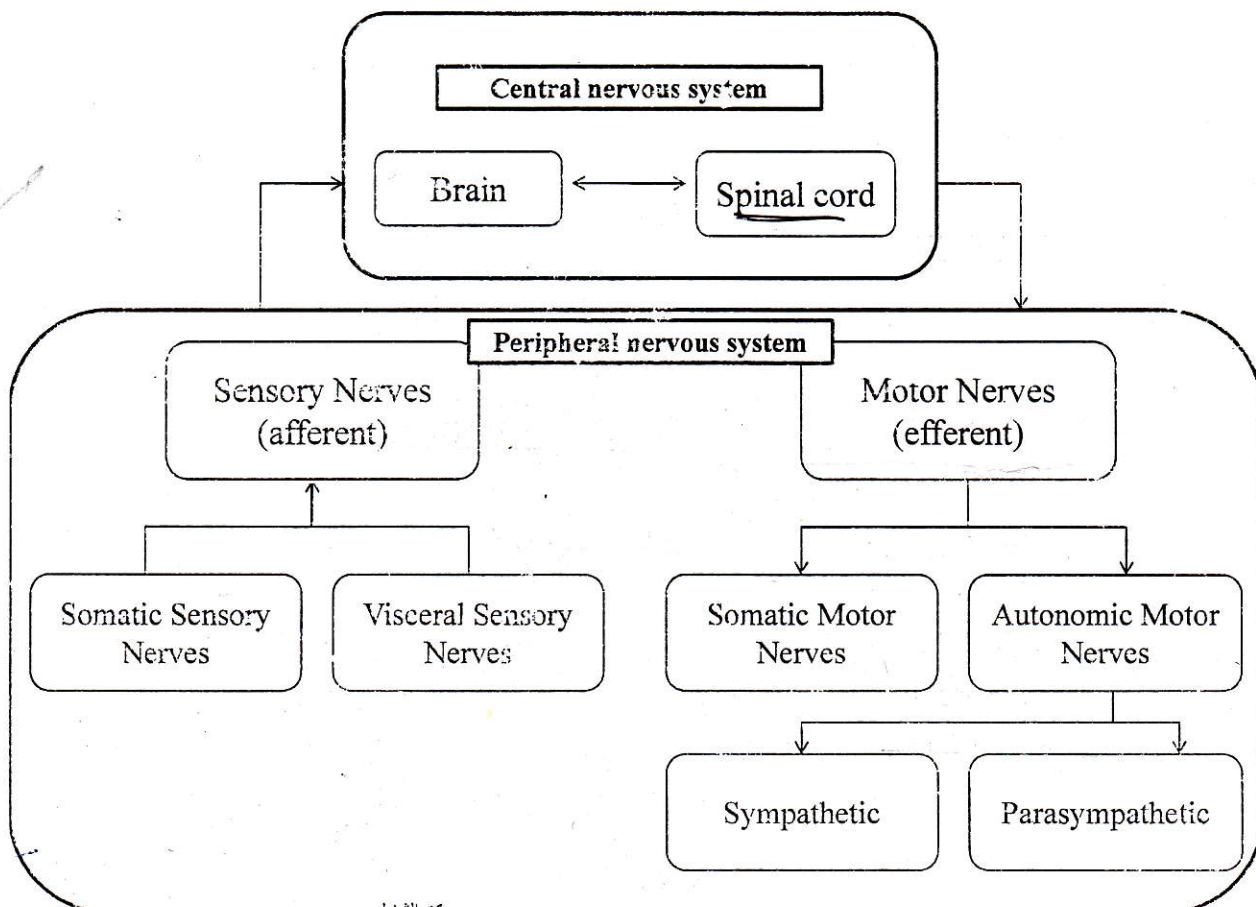
The Motor Nervous System

1) The Motor Function of the Spinal Cord



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Types of motor actions

- There are three classes of movement: voluntary, reflexive and rhythmic
 - 1) Voluntary movements are:
 - a- Complex actions - reading, writing, playing piano
 - b- Purposeful, goal-oriented
 - c- Learned - improve with practice
 - 2) Reflex movements are:
 - a- Involuntary, rapid, stereotyped - e.g. eye-blink, coughing, knee jerk
 - b- Graded according to the eliciting stimulus
 - 3) Rhythmic motor patterns:
 - a- Combines voluntary & reflexive acts - e.g. chewing, walking
 - b- Initiation & termination are voluntary
 - c- Once initiated, they are repetitive & reflexive

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3

Motor nervous system Somatic division

- The motor nervous system perform three functions: ③
 - 1- Causes voluntary activity and involuntary responses
 - 2- Adjust body posture to provide a background for movement
 - 3- Coordinate the action of the muscles to make movements smooth and precise

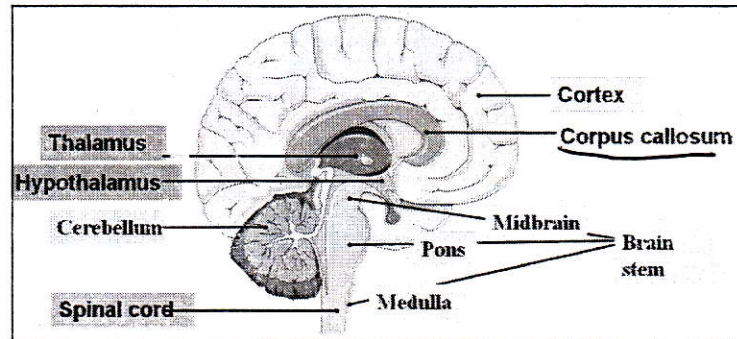
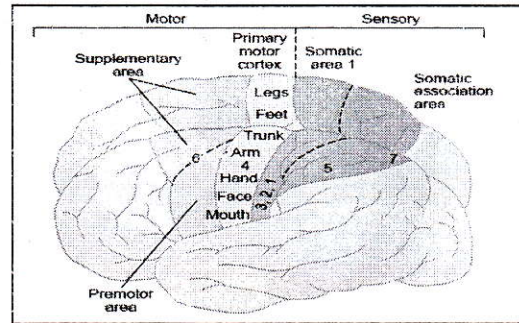
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4

Levels of Control of Motor System (motor system hierarchy)

- The movements can be controlled at many levels of the central nervous system:

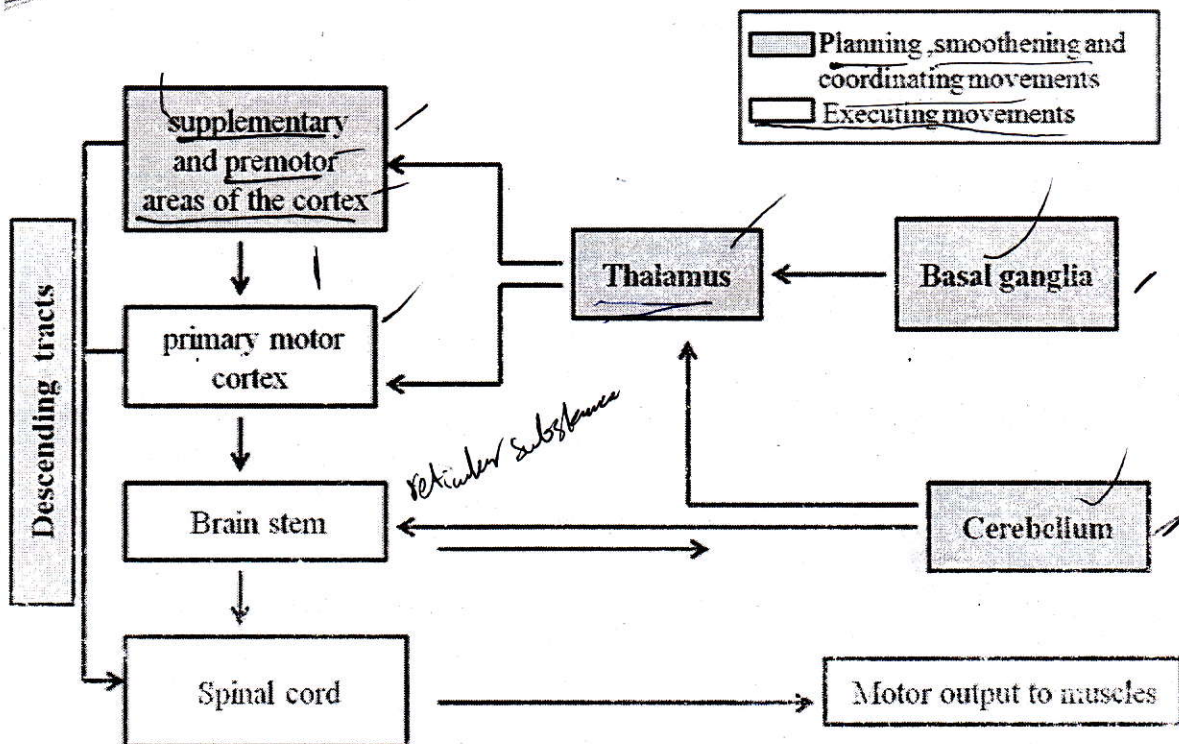
- (1) The spinal cord
- (2) The reticular substance of the brain stem (medulla, pons, and mid brain)
- (3) The motor cortex
- (4) The basal ganglia
- (5) The cerebellum



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5

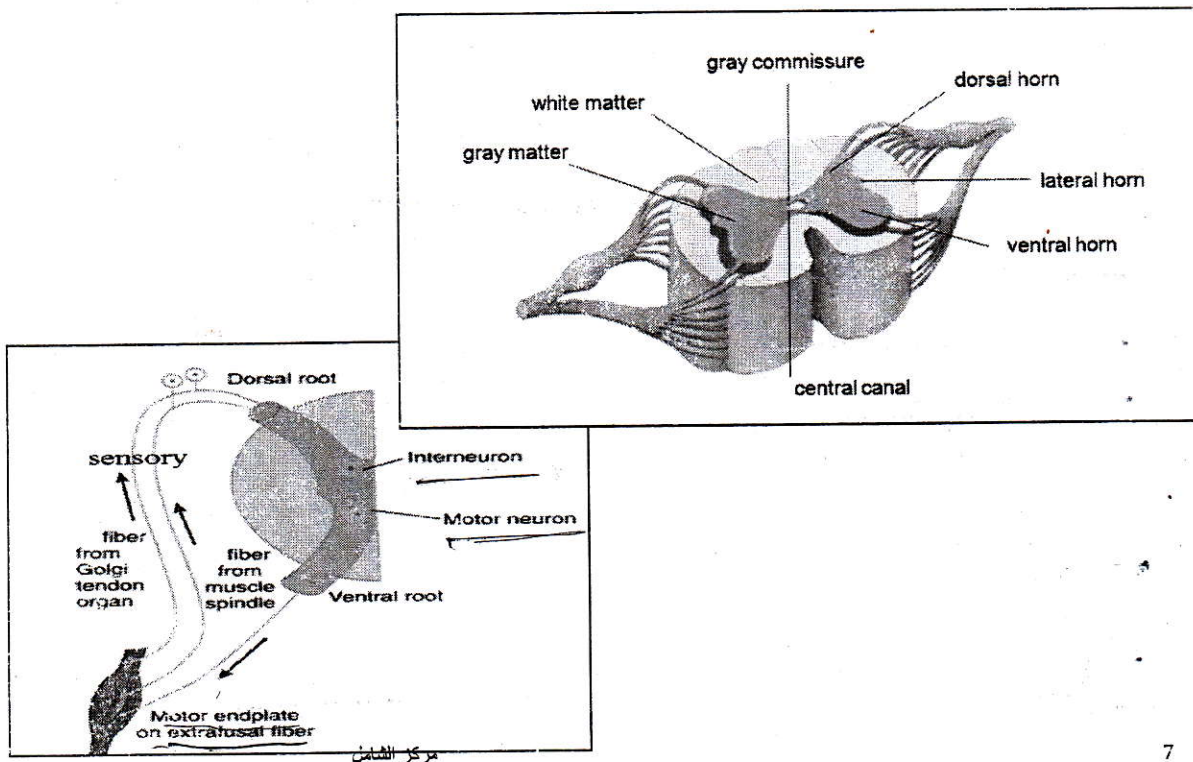
Motor System Hierarchy



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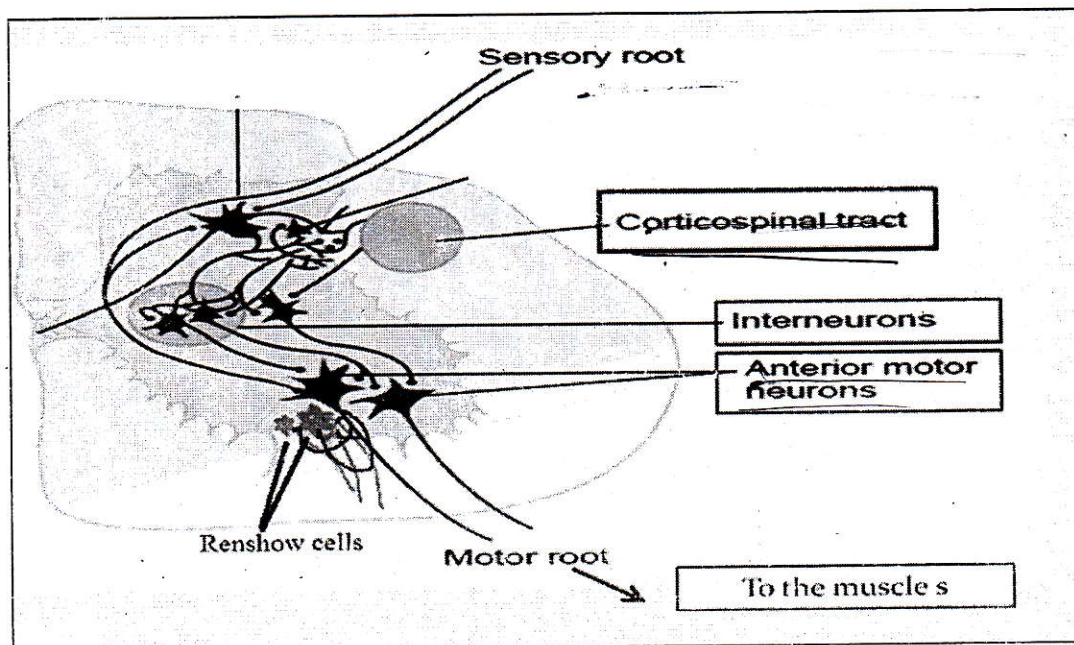
6

Organization of the Spinal Cord for Motor Functions



7

Organization of the Spinal Cord for Motor Functions (...continue)



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8

Organization of the Spinal Cord for Motor Functions (..continue)

❖ Anterior motor neuron are large cells of two types:

- 1) Alpha (α) motor neuron : give rise to large nerve fiber ($A\alpha$) to the muscle. In the muscle it branches several times to innervate from few to hundreds of muscle fibers (motor units) where they control muscle contraction
- 2) Gamma (γ) motor neuron: give rise to smaller nerve fiber ($A\gamma$) goes to muscle spindle to innervate special fibers (intrafusal fibers) that control muscle tone → *Muscle tone*

The anterior motor neurons receive input signals from different higher brain levels and from different levels of spinal cord and send them to the muscles therefore it is the common final pathway of motor system

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9

Small muscles of hand and Antigravity muscles have more number of muscle spindles

Organization of the Spinal Cord for Motor Functions (..continue)

❖ Interneurons :- Large number, small, highly excitable cells

- Responsible of the integrative function of the cord
(diverging, converging and repetitive discharge)
موزع متجمع

❖ Renshaw cells: - Inhibitory cells adjacent to motor neurons

- Branches of motor n. axons synapse with them
- When one motor neuron is firing these cell inhibits the surrounding motor neurons (lateral inhibition)

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10

The Muscle receptors

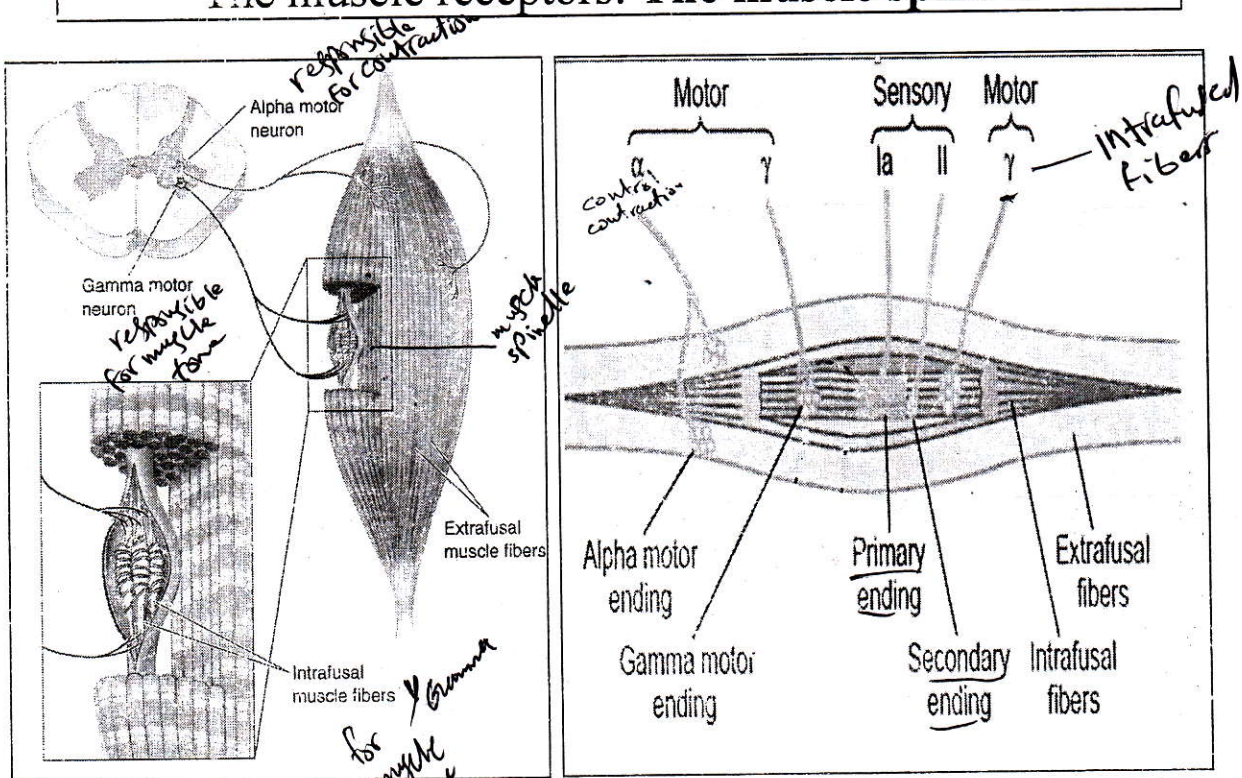
- Feedback information from the muscles to the spinal cord is provided by ^{① stretch receptors} receptors in the muscle fibers (muscle spindle) and muscle tendon (^② Golgi tendon organs)
- Muscle spindle provides ^① information about muscle length and the ^② rate of changes in muscle length
- Golgi tendon organs provide ^① information about tension in the muscle and the ^② rate of change in this tension
- These receptors act at the ^{مركز الوعي} subconscious level
- Signals are sent to different nervous system levels to finally control muscle contraction

The purpose ^{مركز الشامل} to control muscle contraction

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Muscle spindle and golgi tendon receptors act at the subconscious level.

The muscle receptors: The muscle spindle

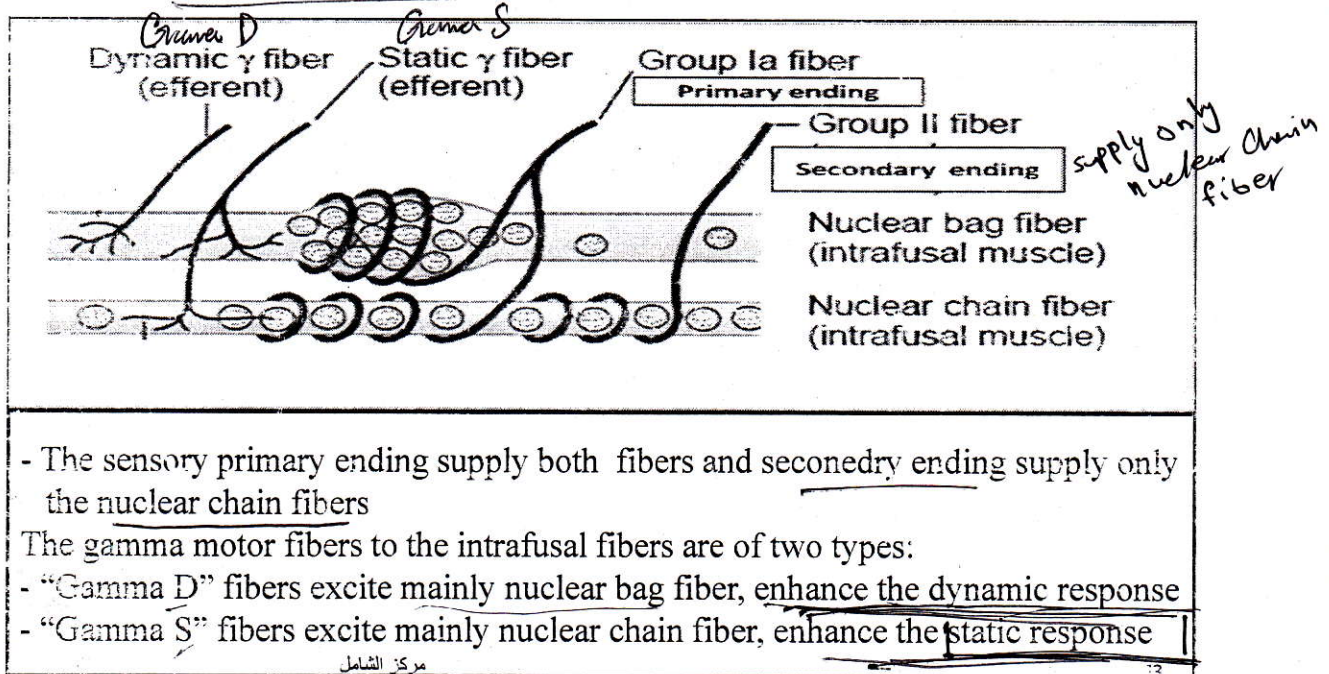


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12

The muscle spindle (continue)

The intrafusal fibers are of two types : nuclear bag and nuclear chain fibers classified according to the arrangement of their nuclei.



The muscle spindle (continue)

Slow stretch of the spindle

- Both primary and secondary sensory endings respond by increase their rate of discharge in proportion to the degree of stretch
- Discharge continued for minutes after the stretch had ends

Static response

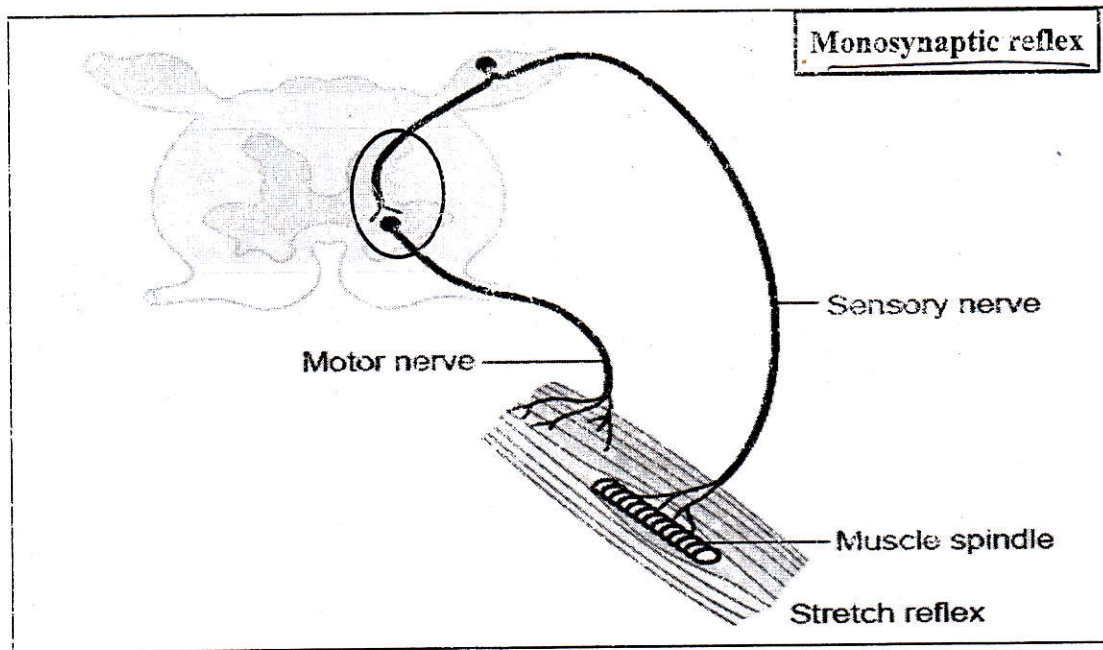
Sudden, rapid stretch of the spindle

- Only primary endings respond by tremendous increase in rate of discharge during the time of stretch
- Discharge stops when the stretch ends

Dynamic response

The opposite response occurs when the muscles shorten (decrease rate of firing to subnormal levels)

The muscle stretch reflex



It is an involuntary reflex action that can occur even if the spinal cord is separated from the rest of the brain

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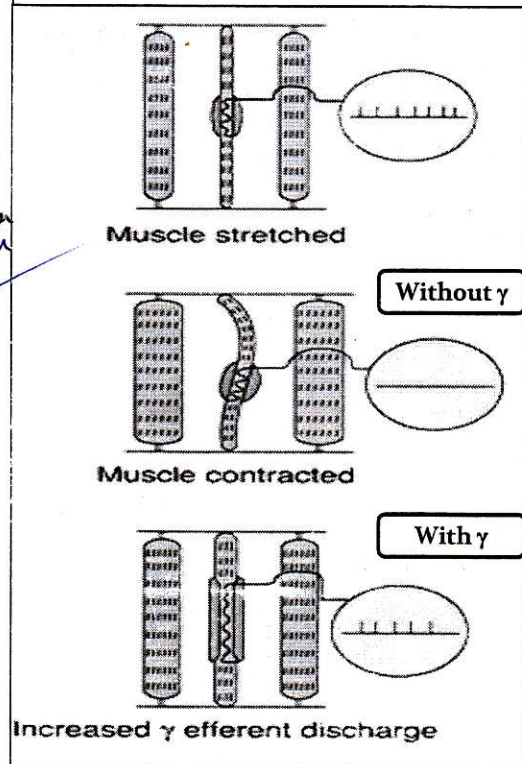
The muscle stretch reflex

- Muscle stretch reflex is the simplest reflex involve muscles and spinal cord circuit it is a monosynaptic reflex
- Whenever the muscle is stretched a reflex contraction occur in its fibers
- Sudden stretch of the muscle to a new length stimulates primary sensory endings in the muscle spindle, fibers enter the spinal cord through dorsal root to the anterior horn, synapse with α and γ motor neuron
- α Motor neurons stimulate muscle contraction to oppose the stretch (dynamic response)
- The dynamic response fades up very rapid, then followed by the static response to hold the muscle at the new length for the required time
- When the muscle change into new length the process repeated

The Gamma motor neuron

- Supply the intrafusal muscle fibers
- Whenever the α motor neuron is stimulated, the γ neuron is stimulated too (co-activation)
- γ neuron is controlled also by higher brain centers *but cerebellum and subthalamic Area facilitate gamma*
- This causes the both extrafusal and intrafusal muscles to contract almost at the same time
- **This is important for:**
keeps the spindle length from shortening during the whole muscle contraction to avoid opposing muscle contraction)

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17

The importance of muscle stretch reflex

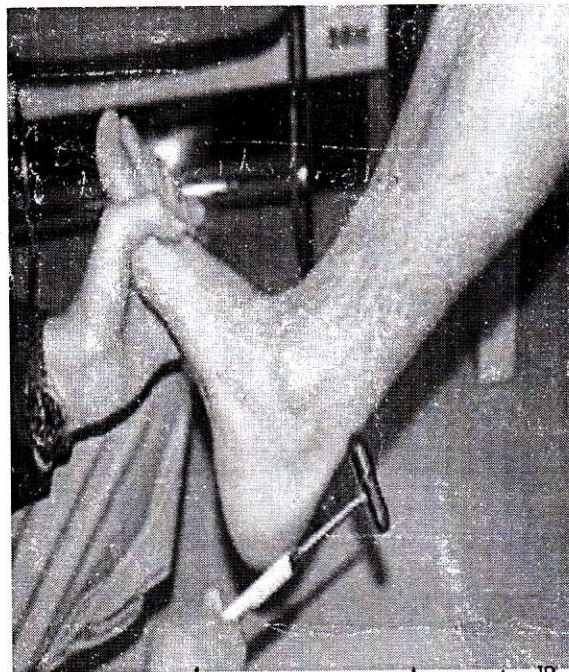
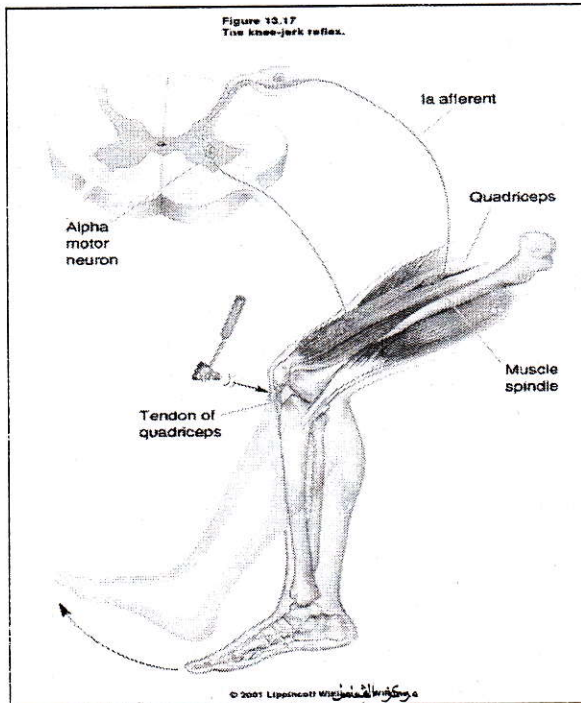
- Experiments showed that the dynamic and static responses of the spindle function in signal averaging called Damping function to prevent jerkiness of muscle contraction
- Genesis of muscle tone
- Production of heat
- Adjust muscle contraction to the load

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18

Clinical application of stretch reflex

Testing deep tendon reflexes



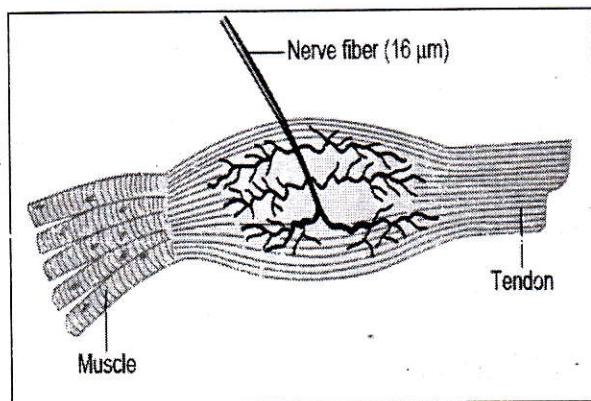
- The purpose is to determine how much background excitation or tone the brain is sending to the spinal cord.
- to determine the presence or absence of muscle spasticity following lesions in the motor areas of brain or muscle spasticity in diseases that excite the bulbo reticular facilitatory area of the brain stem.

The muscle receptors: Golgi tendon organs

- Golgi tendon organs located in the muscle tendon in connection with muscle fibers termination

- They have both static and dynamic response

- They detect muscle tension and the change in muscle tension so provide the nervous system with continuous information on the degree of tension in each segment of each muscle



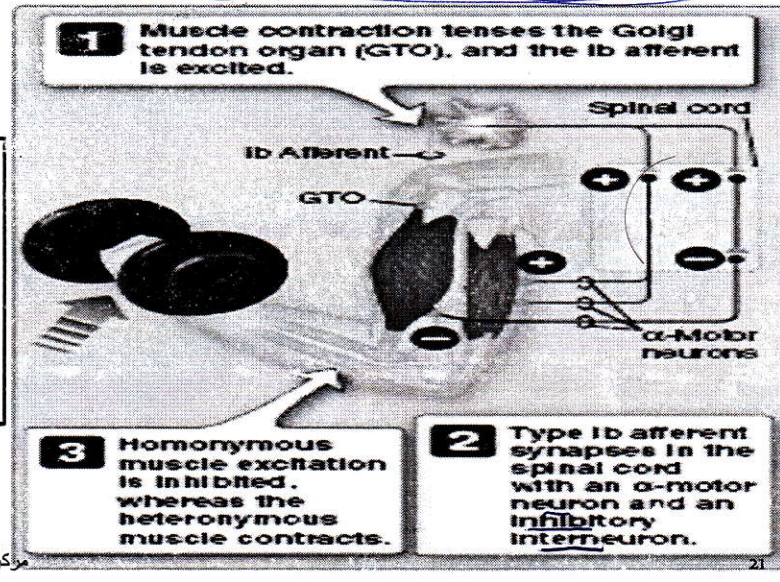
The muscle receptors: Golgi tendon organs

- Golgi tendon organs stimulation cause inhibitory response (protective response)
- Whenever the muscle excessively stretched, tension is proportionally raised ↑
- Tendon organs send signals to relax the muscle to prevent muscle damage

The reflex from Golgi tendon organs is called **the inverse stretch reflex**

it occurs side by side with the muscle stretch reflex

Di-synaptic reflex



Function of the Muscle Spindles and Golgi Tendon Organs in Conjunction with Higher Levels of the Brain for more complex reflexes

- Signals from muscle spindle and Golgi tendon organs are usually send to different levels of spinal cord as well as to the higher brain centers (brain stem, cerebellum, cortex)
- Signals from higher centers integrated in the spinal cord and give more complex reflexes to control movements
 - 1- Flexor (Withdrawal) reflexes
 - 2- Crossed extensor reflex
 - 3- Reflexes of posture and locomotion
 - 4- Muscle spasm
 - 5- Autonomic reflexes

pain reflex

1- Flexor and withdrawal reflexes

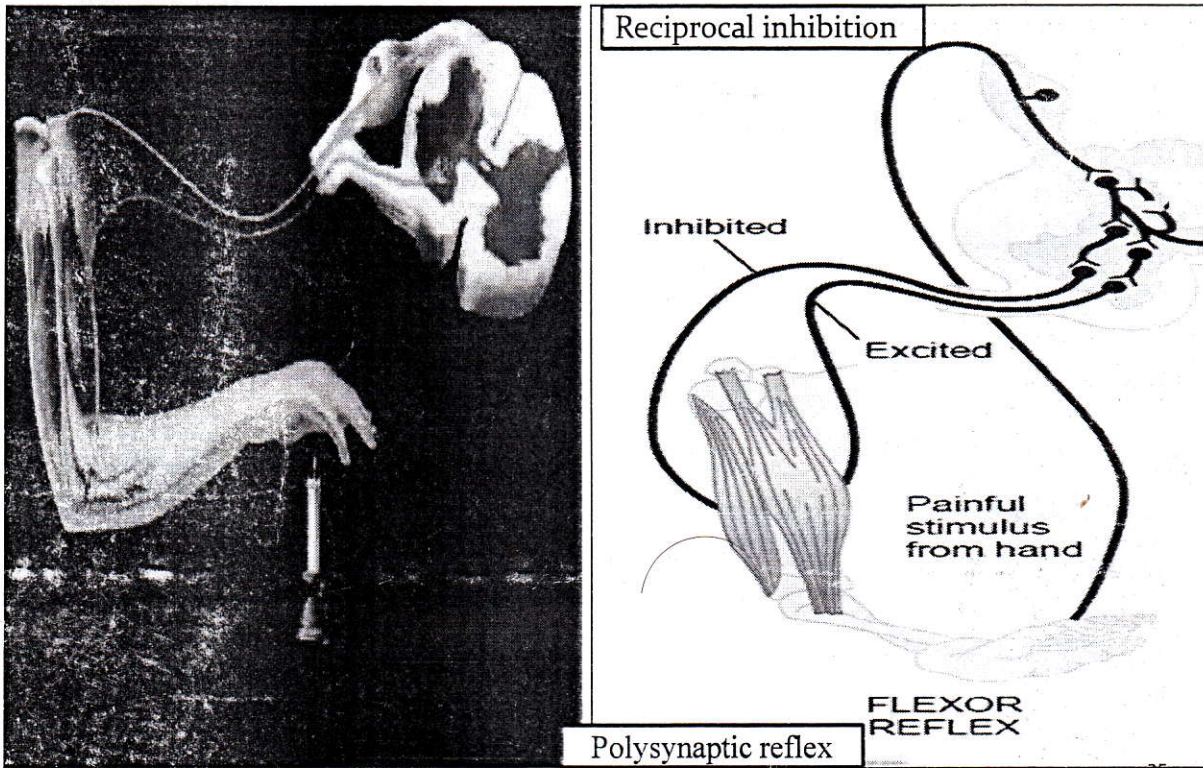
- Cutaneous sensory stimulus like pain or touch from a limb cause the flexor muscles of the limb to contract, withdrawing the limb from the stimulating object.

This is called the flexor reflex

nociceptive reflex

- When the reflex is not confined to flexor muscles of a limb, but other parts of the body also move away from a strong stimulus, this is called withdrawal reflexes

Neuronal Mechanism of the Flexor Reflex

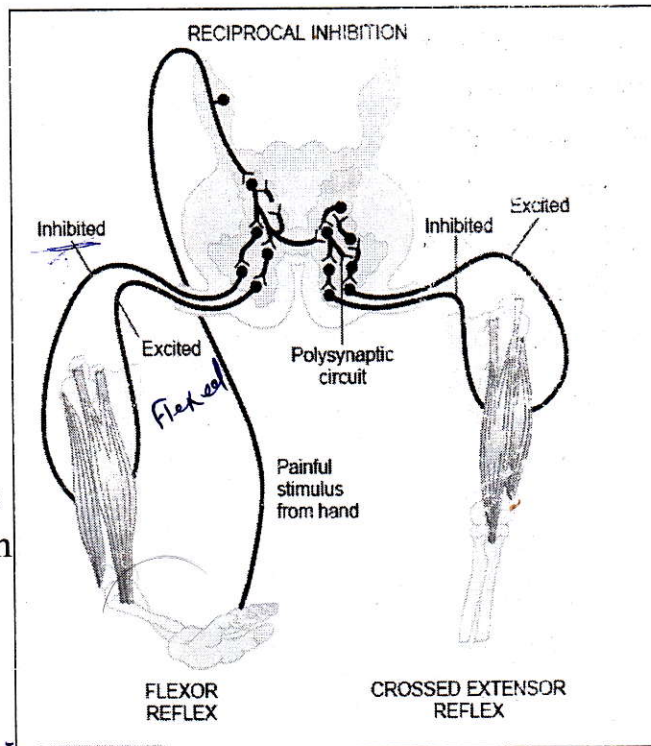


Flexor and withdrawal reflexes(continue..)

- To illicit flexor reflex the sensory neuron do not synapse directly to the anterior motor neurons but pass first into the spinal cord pool of interneurons then secondarily to the motor neurons.
- The interneuron pools involve:
 - (1) Diverging circuits to spread the reflex to the necessary muscles for withdrawal
 - (2) Reciprocal inhibition circuits to ^{تثبيط}inhibit the antagonist muscles
 - (3) Circuits to cause after-discharge lasting many fractions of a second after the stimulus is over (the duration of after discharge is proportional to the intensity of the stimulus)
- The flexor and withdrawal reflexes are polysynaptic reflexes

2- Crossed Extensor Reflex

- The stimulus that elicits a flexor reflex in one limb, cause the opposite limb to extend after 0.2-0.5 sec.
- Signals from sensory nerves cross to the opposite side of the cord to excite extensor muscles
- The reflex continue for few seconds due to after discharge to hold the limb away from the pain source
- Which type of circuits are involved in this reflex??
 - diverging circuits
 - reciprocal inhibition ^{مركز الشامل} circuits
 - after discharge ~~reflex~~ circuits



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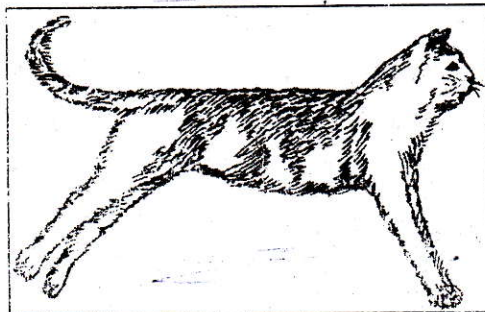
3- Reflexes of Posture and Locomotion

In a spinal animal:

The spinal cord is transected so that all the signals from the higher brain levels are lost. **In this animal the cord reflexes are released**
The resulting reflexes involves a complex neuronal circuits of the cord

a- Positive Supportive Reaction (magnet reaction):

- Pressure on the foot pad of one limb extend that limb against pressure
- Limb extension occurs in the direction of pressure to support the limb and prevent animal fall to that side



b- Cord "Righting" Reflexes:

- Animals laid on their side make incoordinate movements trying to return to right position

3- Reflexes of Posture and Locomotion

c- Stepping and Walking Movements:

- Rhythmical stepping of a single limb:

When a limb is stimulated; forward flexion of that limb is followed a second or so later by backward extension occurs in cyclic form.

This results from oscillation in the circuits that control agonist and antagonist muscles

reciprocal innervation



- Reciprocal stepping of opposite limbs:

Every time stepping forward occurs in one limb, the opposite limb moves backward. This effect results from reciprocal innervation between the two limbs.

3- Reflexes of Posture and Locomotion (continue..)

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- **Diagonal stepping of all four limbs:** when the stimulus is applied unequally to the limbs of hanged animal, the four limbs make stepping movements.

In this case the reciprocal innervation circuits involves the whole cord up and down

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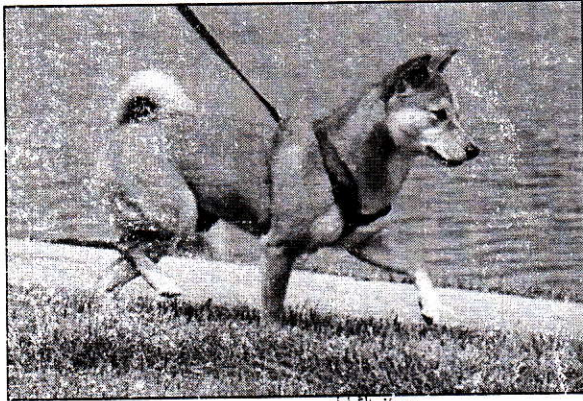
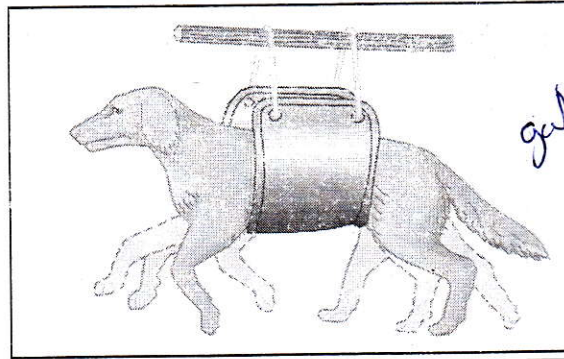
- **Galloping reflex:** both forelimbs move backward and hind limbs move forward at the same time (result from simultaneous stimulation of limbs on both side of the body) like striking the limbs on the ground

The circuits responsible for walking movements even after spinal cord is transected are intrinsic circuits in the spinal cord called **Locomotion generator circuits**

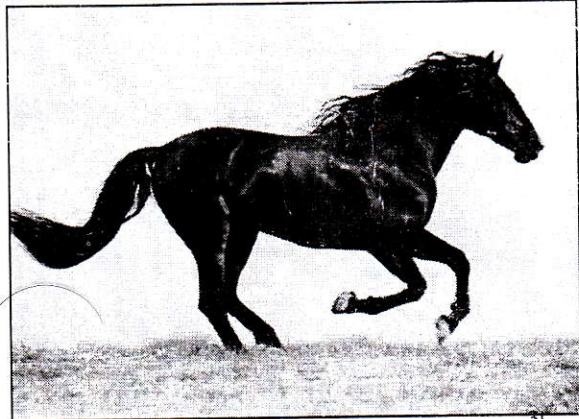
There are two locomotion pattern generators in the spinal cord: one in the cervical region and one in the lumbar region. Their work depends on reciprocal inhibition between agonist and antagonist muscles

Normally these circuits turned on by tonic discharge of an area in the midbrain

Reflexes of Posture and Locomotion



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4- Spinal reflexes causing muscle spasm:

- Muscle spasm around broken bone
- Abdominal muscle spasm in peritonitis
- clunky Abdominal surgery

5- Autonomic reflexes in the spinal cord:

- Changes in vascular tone resulting from change in local skin heat
- GIT reflexes
- Mass reflex: excitation of large portions or all the cord e.g. due to severe pain resulting in:
 - 1- a major portion of skeletal muscles develops strong flexor spasm
 - 2- The colon and bladder are evacuate
 - 3- The arterial pressure often rises to maximal values
 - 4- Profuse sweating

Spinal Shock

- Results from sudden transection of the spinal cord in the upper neck
- At first, depresses all cord functions, including the cord reflexes, this is called state of spinal shock
- This occurs because all signals from the higher centers that control the spinal cord are cut
- After a few hours to a few weeks, the spinal neurons gradually regain their excitability (sometimes hypo and some other times become hyper excitable)
- During spinal shock:
 - 1- The arterial blood pressure falls but returns to normal within a few days
 - 2- All skeletal muscle reflexes integrated in the spinal cord are blocked.
Then they return back starting with the simplest to the more complex one
 - 3- The sacral reflexes for bladder and colon evacuation are suppressed in the first few weeks after cord but in most cases they return

PHYSIOLOGY OF THE NERVOUS SYSTEM

The Motor nervous system

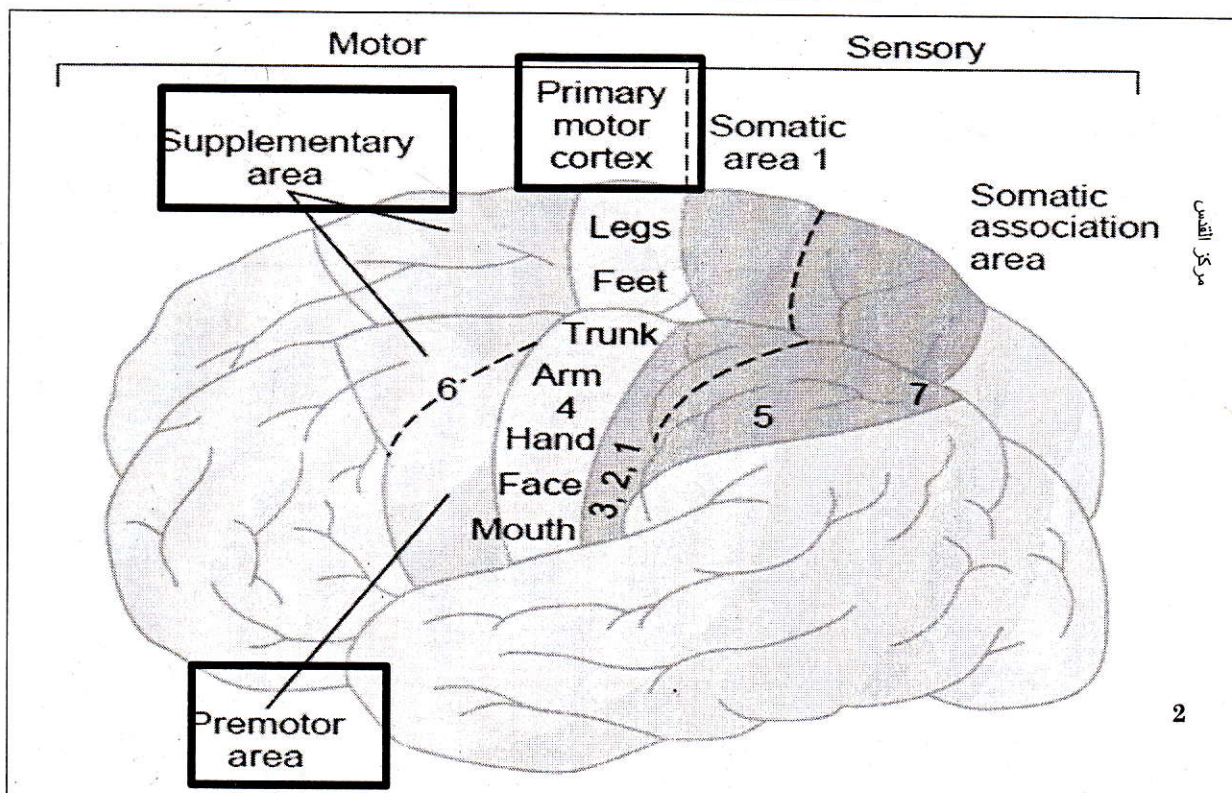
2) CORTICAL CONTROL OF MOTOR FUNCTION

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1

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The motor cortex



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The motor cortex

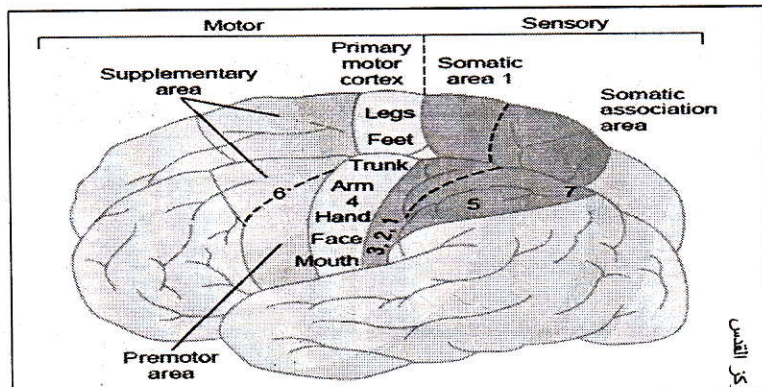
- The functional motor area of the cerebral cortex located anterior to the central sulcus.
- The motor cortex is divided into three subareas, each has its own topographical representation of muscle groups and specific motor functions:
 - (1) The primary motor cortex (area 4)
 - (2) The premotor area
 - (3) The supplementary motor area

(area 6)

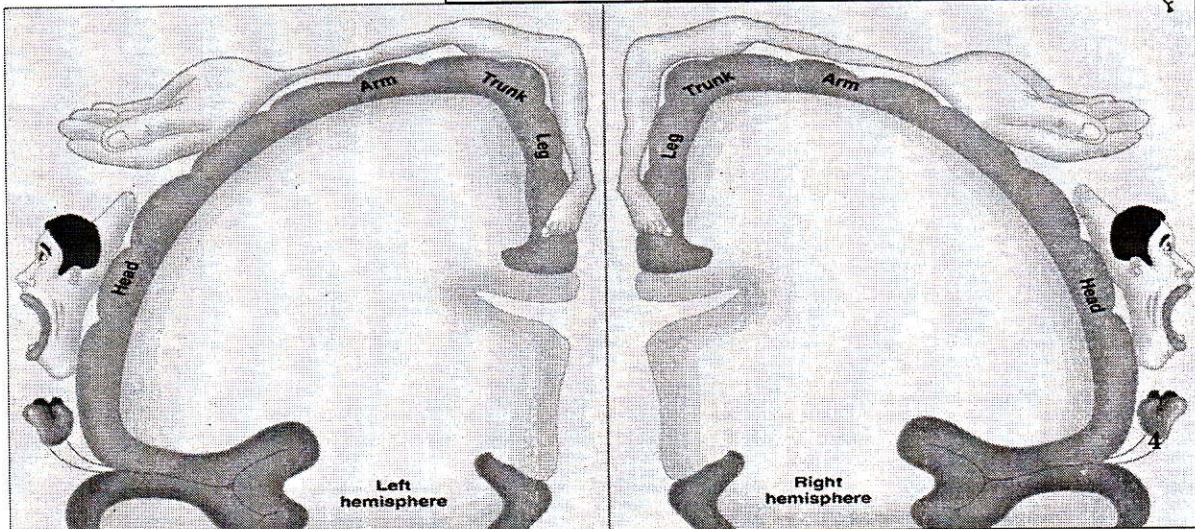
مركز القبس

3

1) The primary motor cortex (area 4)



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The primary motor cortex (area 4)

- Located just anterior to the central sulcus (precentral gyrus)
- Body parts are represented upside down
- Upper part of the face is represented bilaterally
- Areas representing body parts on the motor cortex is proportional to the skills done by this part.
Therefore the hands and face muscles (especially muscles of speech) are represented by larger areas than the rest of the body
- Each cortical area controls muscles on the opposite side of the body

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The primary motor cortex (area 4)

- Excitation of primary motor area causes direct and discrete muscle contraction
- But in the areas that represent the highly skillful parts;
excitation of a single motor neuron excite specific movement (group of muscles) rather than one specific muscle

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The premotor and supplementary motor cortex (area 6)

Nerve signals from these areas cause much more complex patterns of movement rather than discrete muscle contraction

These areas work together in:

- 1- Cortical programming of motor activity: translate the image and knowledge of the required movement into sequence of motor commands to perform the movement
 - 2- Transmit signals from other areas of the cortex and basal ganglia to primary motor cortex
 - 3- Their stimulation cause fixation movements of the different body parts and coordinate the movements of the head and eyes
- These actions provide background for the finer movements of the arms and hands

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The Premotor Area

- The topographical organization of the premotor cortex is roughly the same as that of the primary motor cortex
- In addition to other functions, this area stores the memories of learned motor actions
- Lesions in this area leads to:
 - 1- Motor apraxia (inability to do the action without paralysis)
 - 2- Reappearance of grasp reflex (normal in infants)

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8

Motor apraxia inability to perform movements necessary to use objects properly, Although the names and purposes of the objects are known and understood.

The Supplementary Motor Area

- In addition to the other functions :stimulating this area causes bilateral contractions ; so it is important for bimanual coordination
(e.g bilateral grasping movements of both hands simultaneously)
- Lesion in this area leads to loss of bimanual coordination
- This area is important specially for orientation of body in space

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9

Specialized areas of motor control in the human cortex

Laying within the premotor and supplementary areas:

1) Broca's area

- Is the “word formation” area
- This area controls the muscles of articulation (lips, tongue, jaws...)

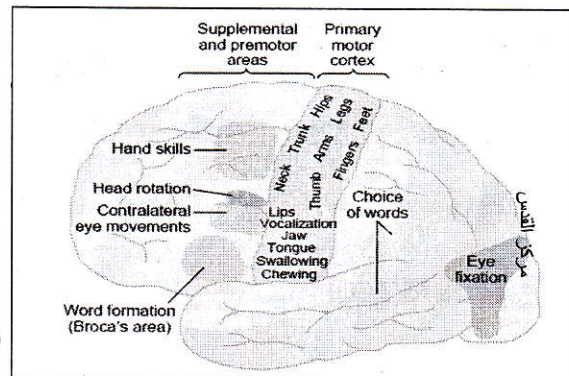
2) Voluntary Eye Movement area:

- Controls eye movements towards an object

3) Head Rotation Area:

- Control head rotation towards an object in association with eye movement

4) Area for Hand Skills: controls fine hand movements



10

Brain Plasticity

- The motor cortex shows a phenomenon called plasticity
- Plasticity is the change in the size of the brain area that represent the body part according to learning and practice
- For example, the finger areas of the motor cortex enlarge as a pattern of rapid finger movement is learned
- This change is detectable at 1 week and maximal at 4 weeks.
- Thus, the maps of the motor cortex are not absolute, and they change with experience.

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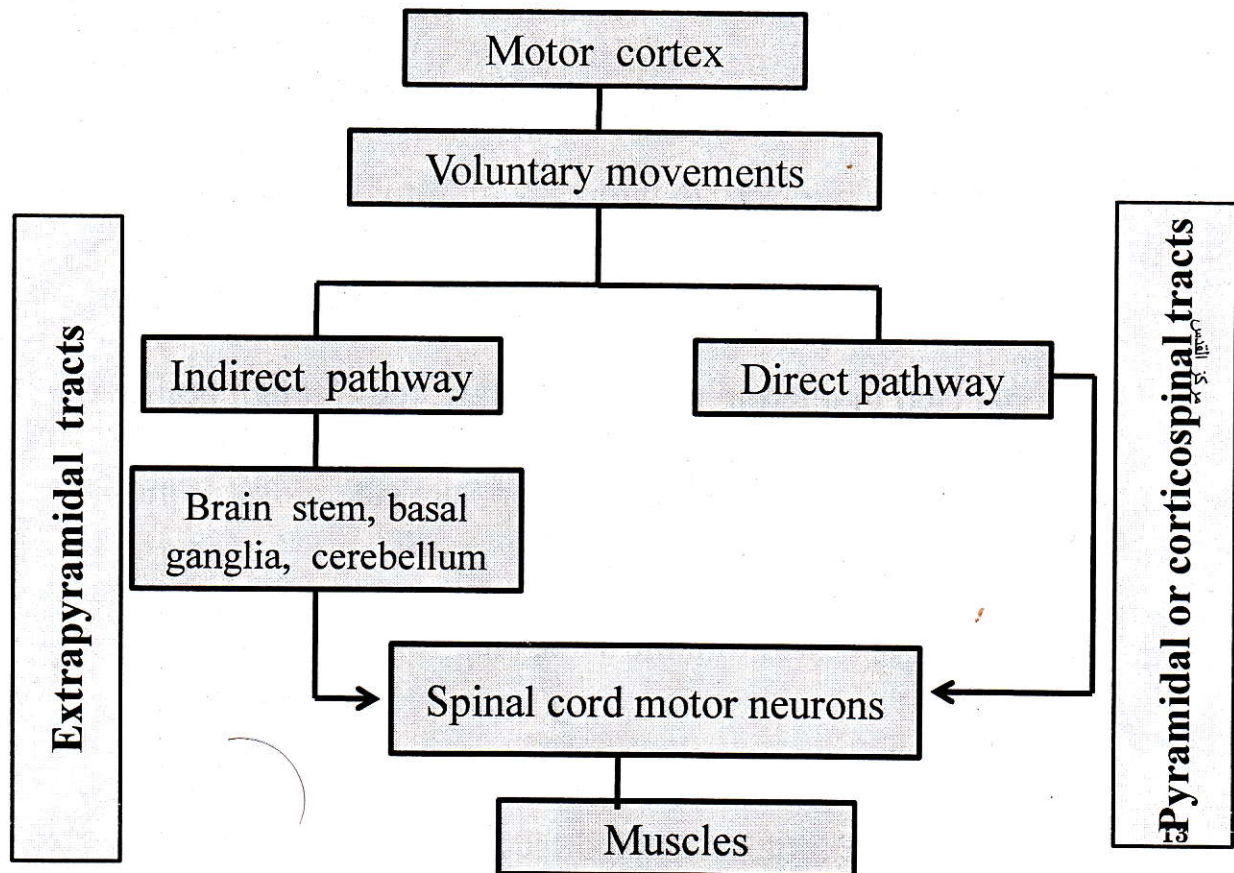
11

Signal transmission from motor cortex to the muscles

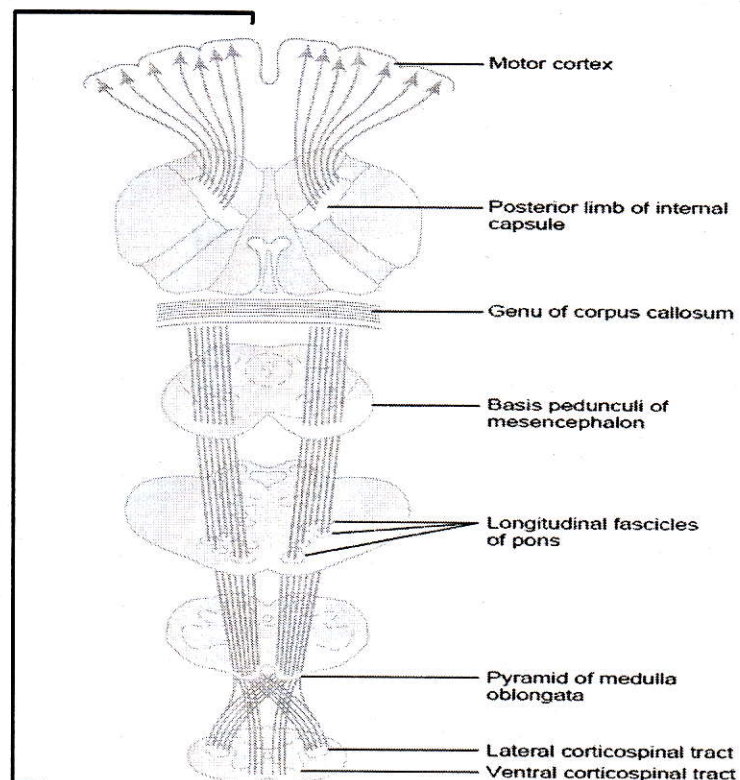
- Signal transmission involves two pathways
- **Direct pathway** from motor cortex to muscle through **pyramidal tracts** (cortico-spinal tract)
- **Indirect pathway** to muscles through **extra pyramidal tracts**; multiple accessory tracts that involve the basal ganglia, cerebellum, and various nuclei of the brain stem

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12



The cortico-spinal tracts (pyramidal tracts)



The cortico-spinal tracts (pyramidal tracts)

- 30% of the fibers are from the primary motor cortex, 30% from the premotor and supplementary motor areas, and 40% from the somatosensory areas
- Fibers collected in internal capsule and descend through brain stem
- The majority of fibers cross into the opposite side in lower medulla forming the lateral corticospinal tracts
- The rest of fibers descend in the same side forming ventral corticospinal tract
- Most of the fibers terminate on the interneurons of the cord and few on the anterior motor neuron directly

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The cortico-spinal tracts (continue..)

- Lateral tracts mainly controls skilled movements of distal limb muscles
- Ventral tracts involved in control of bilateral postural movements (axial and proximal muscles)
- In addition fibers from the cortex synapse in the nuclei of the cranial nerves of brain stem then form the corticobulbar tracts (Trigeminal, facial and hypoglossal cranial nerves)
Their axons pass the same pathway as corticospinal tracts into face muscles

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The extra-pyramidal system

- All tracts other than the corticospinal is called extrapyramidal tracts
- These fibers in these tracts come from motor cortex and branch into **several areas** before descending into spinal cord forming the extra pyramidal tracts.
- The most important tracts are descending from :
 - 1- Mid brain (Rubrospinal and Tectospinal tracts)
 - 2- Pons and medulla reticular formation (Reticulospinal tracts)
 - 3- Vestibular nucleus in brain stem (vestibulospinal tract)
 - 5- Fibers from nuclei of basal ganglia

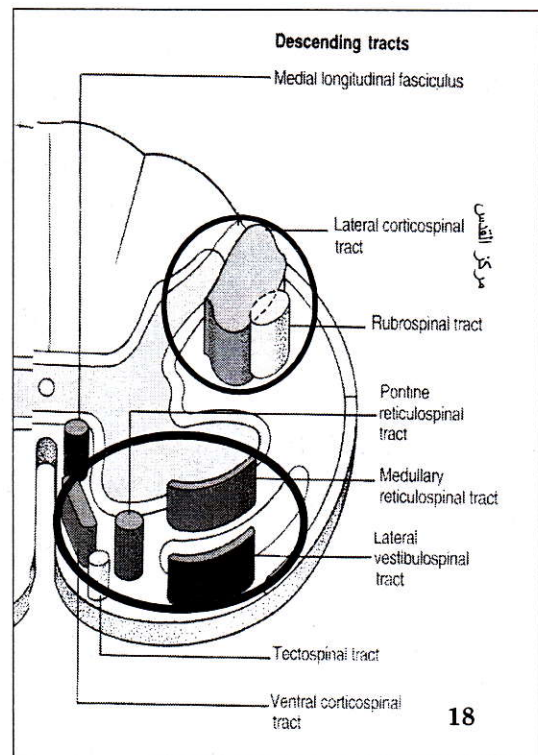
17

The lateral and medial (ventral) motor systems

The descending tracts classified into lateral and medial (ventral) systems:

The lateral corticospinal and rubrospinal tracts together form the lateral motor system of the cord for control of distal limb muscles for skilled movements

The ventral corticospinal tract and the other extrapyramidal tracts form the medial motor system that control the axial and proximal limb muscle concerned with posture and gross movements



18

Upper and Lower Motor Neurons

- Upper motor neurons (UMN) refer to neurons of the cortex and brain stem that activate the spinal cord neurons
- Lower motor neurons (LMN) are the anterior motor neurons of the spinal cord and cranial nerves (the final common pathway) and their axons to the muscles
- Upper motor neurons controls the activity of lower motor neurons by either **exciting or inhibiting** their activity

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lesions in Upper and Lower Motor Neurons

- Lesions in UMN include lesions in the cortex or other structures from which descending tracts are come

(any level above the anterior motor neurons of spinal cord)

e.g. Hemiplegia

paralysis of one side of the body usually resulting from damage to the corticospinal tracts of CNS also called hemiparesis. most common cause is stroke caused by thrombosis, brain haemorrhage or cerebral embolism

e.g. Extrapyraxidal syndrom

EPS: Any of several degenerative nervous system diseases that involve the extrapyramidal system and the basal ganglia of brain. The symptoms include tremor, chorea, athetosis and dystonia. Parkinsonism is an extrapyramidal syndrome.

- Lesions in LMN include lesions in anterior motor neurons or their axons to the muscles)

e.g. poliomyelitis

An acute infectious inflammation of the anterior horns of the grey matter of the spinal cord.

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Upper and Lower Motor lesions

	UMN lesion	LMN lesion
Paralysis	Involve movement of limbs or half body	Involve muscles innervated by single nerve
Muscle tone	Hyper-tonia (Spasticity) <i>uncontrol of muscle</i>	Hypo-tonia (Flaccidity) <i>soft or wadded instead of firm</i>
Muscle stretch reflexes (deep tendon reflexes)	Hyper-reflexia	Hypo-reflexia
Muscle wasting	Only slight or none	Sever
Babinski's sign	Positive (normal in infants)	Negative

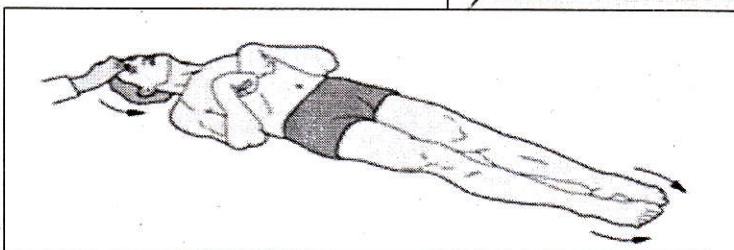
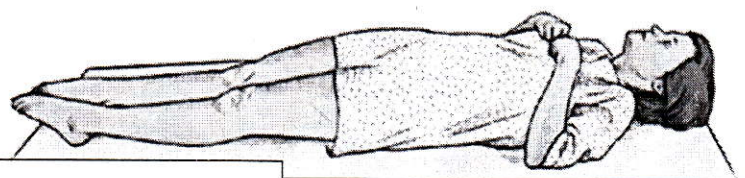
In upper motor neuron lesion, the orders to the anterior motor neurons are cut. So they are released from the effect of higher centers inhibitory of²¹ excitatory signal

Decortication and Decerebration

- Removal of the cerebral cortex produces **decorticate rigidity** which is characterized by flexion of the upper extremities at the elbow and extensor hyperactivity in the lower extremities
- Decorticate rigidity is seen on the hemiplegic side in humans after hemorrhages or thromboses in the internal capsule.

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DECORTICATE

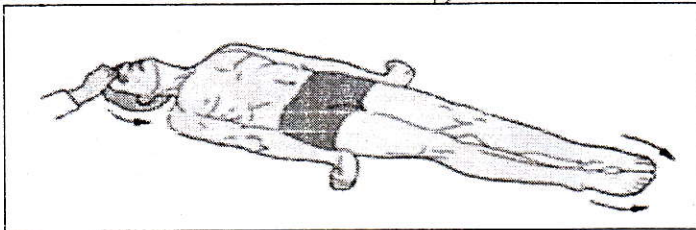
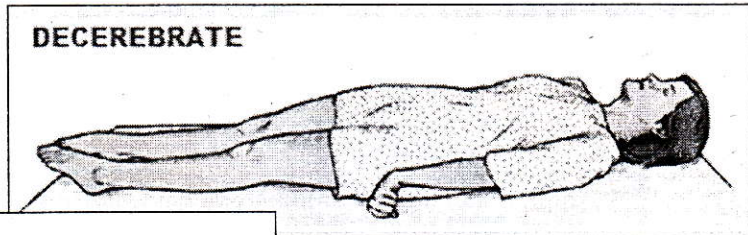


Decortication and Decerebration

- Decerebration means transection of the brainstem at the superior border of the pons. Means removing the mid brain and above structures
- Decerebration results in decerebrate rigidity develops as a result of diffuse facilitation of stretch reflexes by signals from pons and medulla

مركز القاسم

DECEREBRATE



23

○ According to what we studied, think about the following:

○ A patient has the following problems:

- 1- Paralysis of right upper and lower limbs ✓
- 2 - The paralyzed limbs are hypertonic ✓ *HyPertonia*
- 3 - The reflexes are exaggerated *HyPerreflexia*
- 4 - The mouth is deviated to left side *stroke*

HyP Left
مركز القاسم

- 1- Is the lesion in UMN or LMN?
- 2- Explain the mechanism of these signs
- 3- Do you think the lesion in left or right side of motor system

24

Physiology of the Nervous System

The Motor Nervous System

3) Brain Stem Control of Motor Function and the Vestibular System

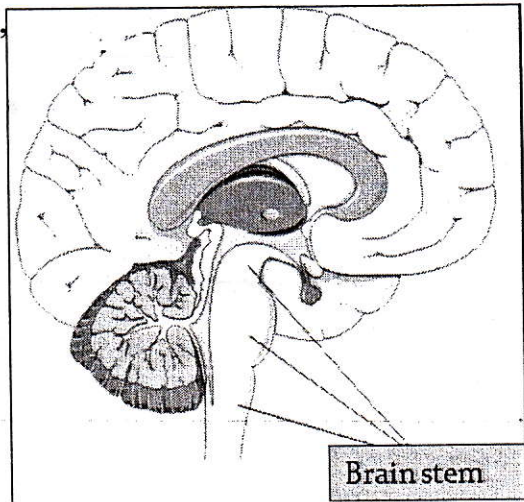
القدس للخدمات المعرفية

القدس للتصوير

1

The Brain Stem

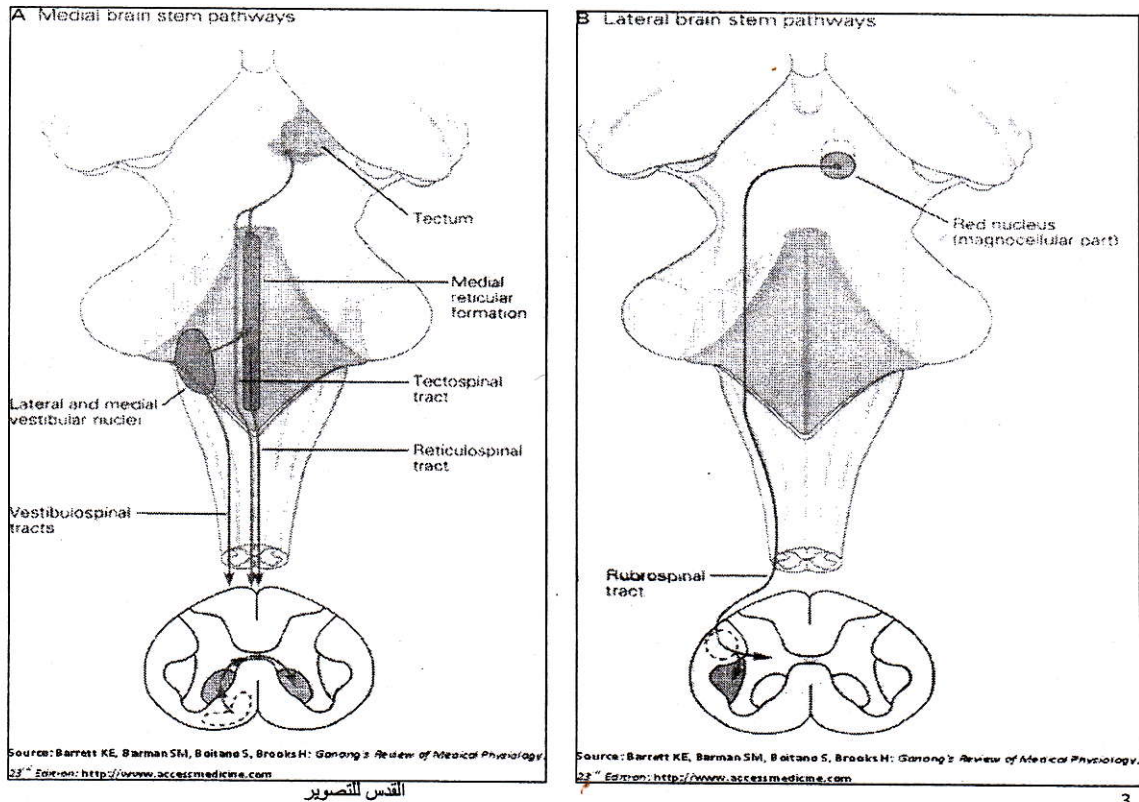
- Composed of the midbrain (mesencephalon), pons and medulla
- It contains motor and sensory nuclei that perform motor and sensory functions for the face and head regions
- Motor control functions:
 1. Control of posture and equilibrium
 2. Control of eye movements
 3. Control of many stereotyped movements of the body
 4. It is a way station for commands from higher centers
 5. Contains control centers for CVS, respiratory and GIT functions



القدس للتصوير

2

The Brain Stem nuclei and tracts



3

The Brain Stem nuclei and tracts

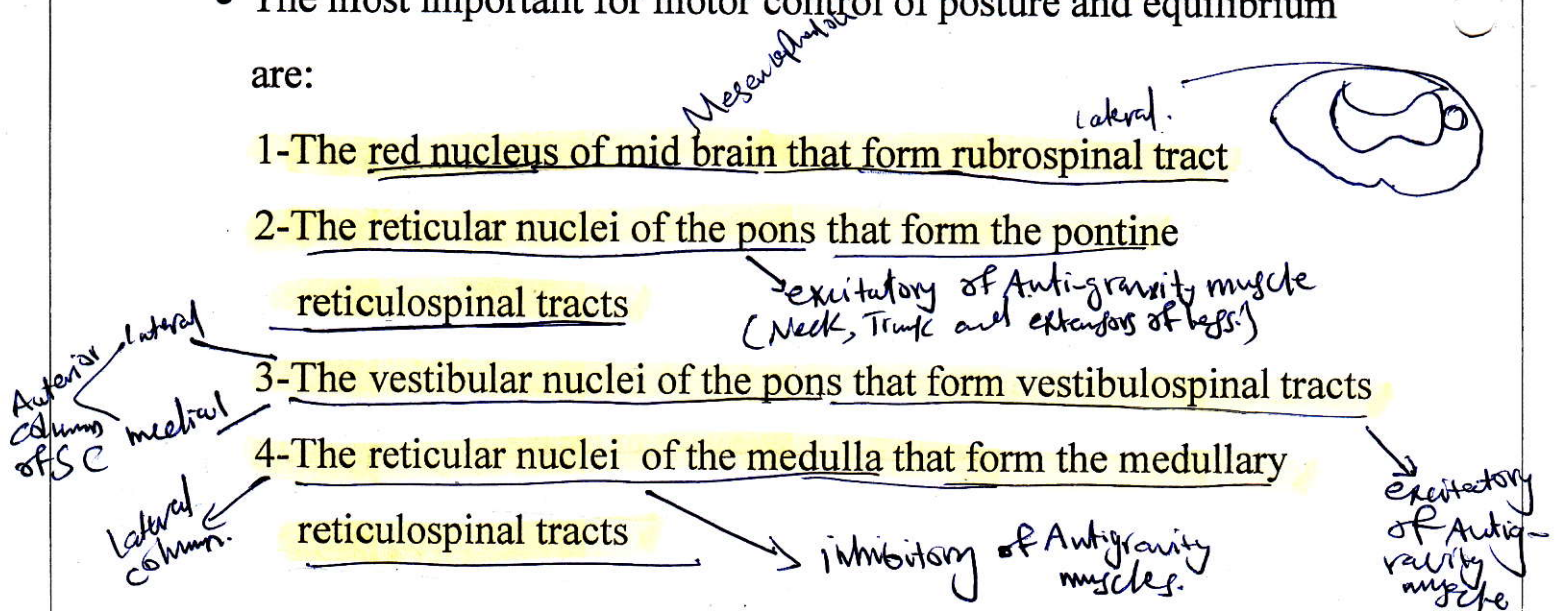
- There are many nuclei and descending tracts from the brain stem.
- The most important for motor control of posture and equilibrium are:

1-The red nucleus of mid brain that form rubrospinal tract

2-The reticular nuclei of the pons that form the pontine reticulospinal tracts

3-The vestibular nuclei of the pons that form vestibulospinal tracts

4-The reticular nuclei of the medulla that form the medullary reticulospinal tracts



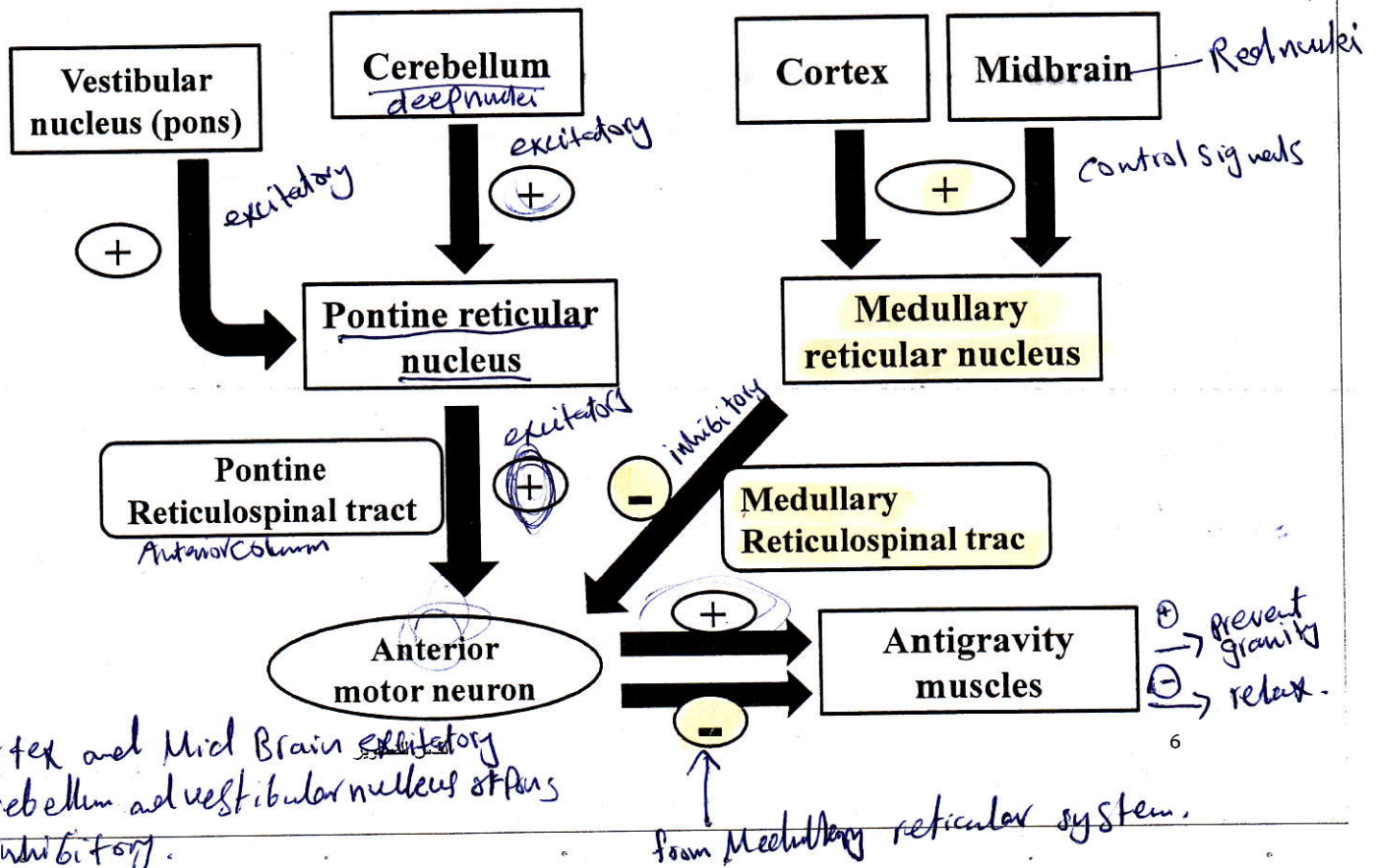
Counterbalance: to have an equal and opposite effect to something.

Support of the body against gravity

- Body support against gravity involve the axial muscles and extensor muscles of the limbs.
Neck Trunk extensors of leg.
- Body support against gravity is the role of reticular nuclei of the brain stem:
Pontine medulla
 - The pontine reticular nuclei excite the antigravity muscles
excitatory.
 - The medullary reticular nuclei relax the antigravity muscles
inhibitory.
- The reticular nuclei counterbalance the effect of each other
Pons Medulla
- The excitatory and inhibitory reticular nuclei is controlled by motor signals from the cerebral cortex and other higher areas
Basal ganglia + cerebellum deep nuclei

التنسيق للتصوير

Support of the body against gravity: Role of pontine and medullary reticular nuclei



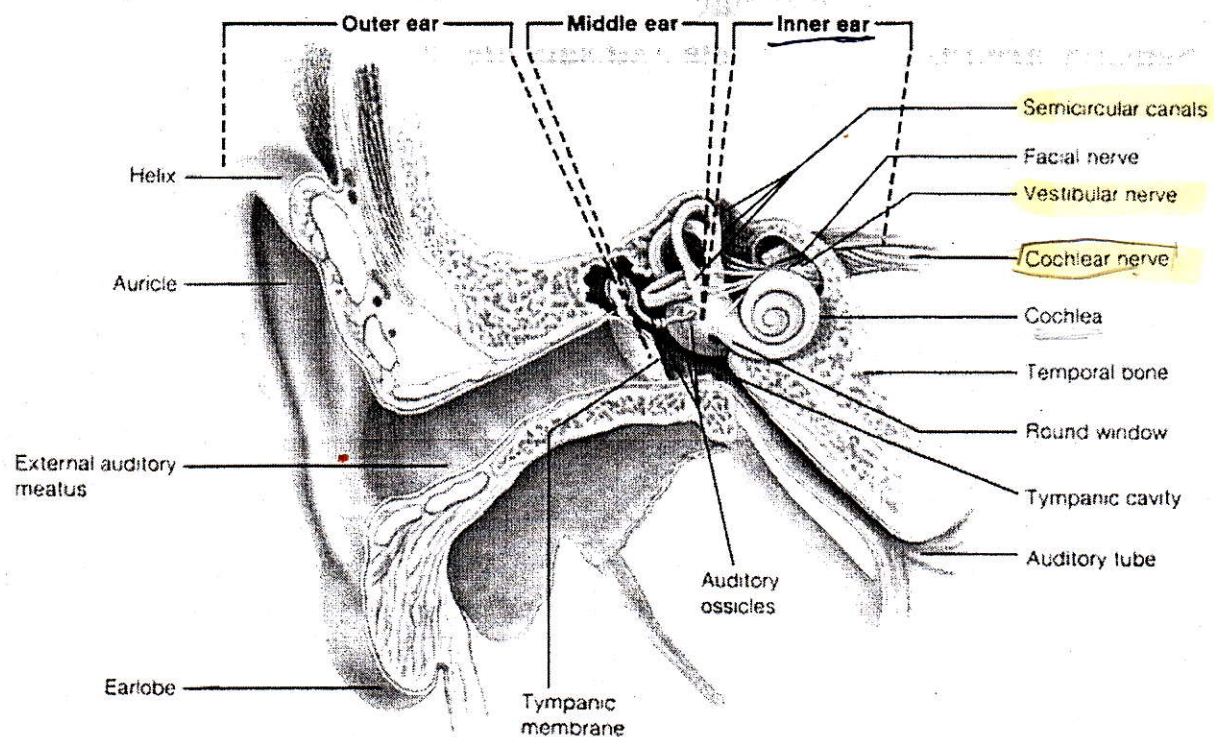
Support of the body against gravity:

Role of pontine and medullary reticular nuclei

- The antagonization between medullary and pontine reticular nuclei prevent powerful over-excitation of antigravity muscles throughout the body by counterbalancing the action of pontine nuclei *excitatory*
- If standing is wished, the medullary nuclei is inhibited by higher centers so the pontine nuclei is excited and extend the antigravity muscles
- Remember the overextension in decerebrate animals? Try to explain it using the functions of reticular nuclei

Blockage of the signals ^{القدس للتصوير} from cerebral cortex and other parts of Higher center in the Decerebrate animals whose Brainstem at the level of mid Brain between level of Mesencephalon with the Pontine, Medullary, vestibular reticular system left intact. The signals to the medullary reticular nuclei will be lost and the Pontine reticular system will be overactive and will send signals to the Anterior motor neurons through pontine reticular tract that will cause rigidity and spasticity of the axial muscles and extensors of limbs

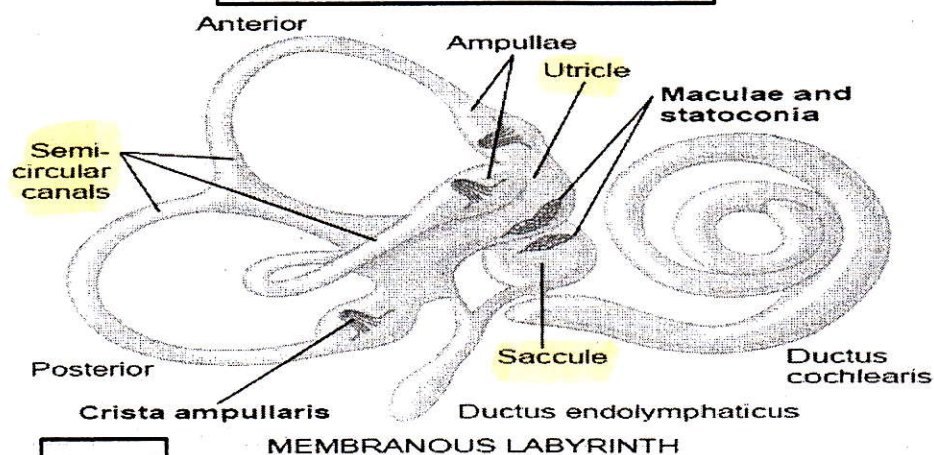
Vestibular Sensations and Maintenance of Equilibrium



التمثيل للتصوير

9

Vestibular Apparatus



Vestibular apparatus is located in the bony labyrinth of the temporal bone. The functional part of vestibular apparatus is called "the membranous labyrinth" of the inner ear

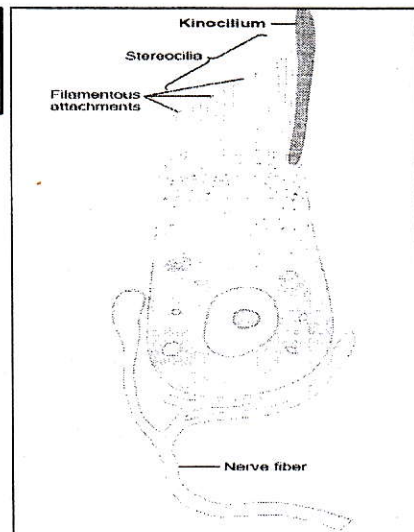
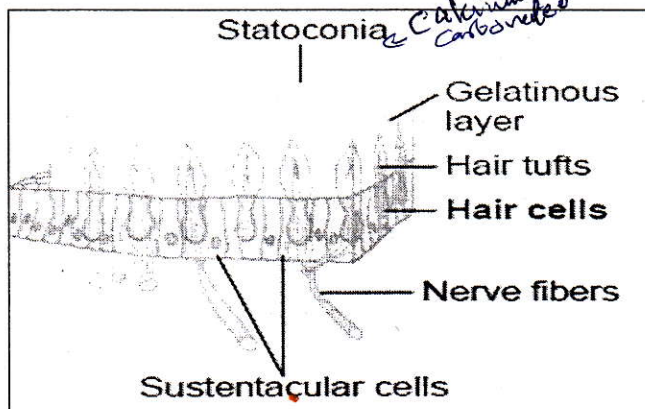
It is composed mainly of the cochlea; three semicircular canals; and two large chambers, the utricle and saccule. *major hearing organ.*

The cochlea is concerned with hearing, while the semicircular canals, the utricle, and the saccule are all integral parts of the equilibrium mechanism.

التمثيل للتصوير

10

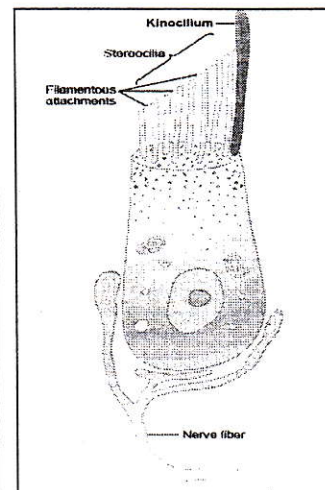
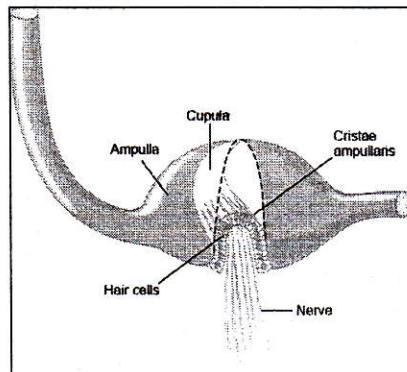
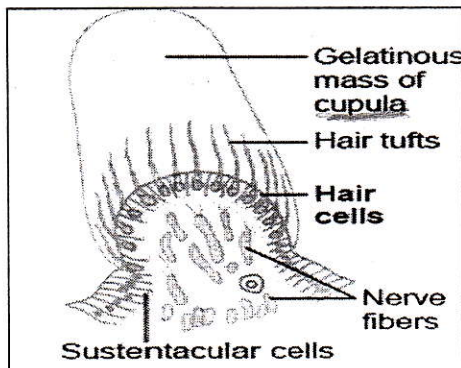
The Maculae (Sensory organs of the utricle and saccule)



The sensory organ inside the utricle and saccule is the “macula”
 The macula of the utricle lies in horizontal plane, while the macula of the saccule lies in vertical plane
 Each macula is covered by a gelatinous layer in which small calcium carbonate crystals called statoconia are embedded
 Thousands of hair cells in the macula project their cilia up into the gelatinous layer and synapse from other side with sensory endings of the vestibular nerve.

القدس للتصوير

The crista ampullaris (Sensory organs of the semicircular canals)



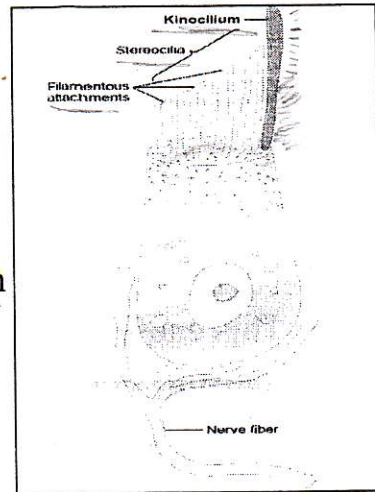
- The sensory organ inside the semicircular canals are the crista ampullaris
- On the top of the crista are gelatinous material called the cupula into which the cilia of the hair cells are projected
- The hair cells are connected with the vestibular nerve fibers
- The semicircular ducts contain a fluid called endolymph
- The three semicircular canals (the anterior, posterior and lateral or horizontal) are arranged at right angles to one another so that they represent all three planes in space



القدس للتصوير

How the hair cells function

- Each hair cell has 50-70 small cilia called stereocilia and one large cilium called kinocilium
- Kinocilium is at one side, and the stereocilia become progressively shorter toward the other side.
- Minute filaments connect the tips of each stereocilium to the next one and finally to the kinocilium.
- At the bases of the cilia there is hundreds of fluid channels that are able to conduct positive ions
- When cilia bend in the direction of the kinocilium, these channels open causing inward flow of positive ions and cell membrane depolarization
- When cilia bend in the opposite direction the channels close causing cell membrane hyper polarization
- Hair cell send signals at static rate that increased during depolarization and decrease during hyperpolarization



13

Major functions of the vestibular system

- **The function of the utricle and saccule:**
 - Detection of head orientation in space (bending the head)
 - Detection of linear acceleration
- **The functions of semicircular canals:**
 - Detection of head rotation (angular acceleration)
 - Prediction of dysequilibrium
- **In addition :**
 - The vestibular system stabilize the eyes to fix the image on the retina during head rotation (control eye gaze)

Detection of head orientation by the maculae of utricle and saccule : (static equilibrium)

- When the head bends in one direction, the heavy statoconia in the gelatinous material move in that direction following the pull of gravity
- This cause bending of the hair cells and change in signal transmission to the vestibular nerve fibers
- The signals from **different hair cells** apprise the brain about the head orientation in space
- The maculae detect head bending in forward, backward and side way directions

القدس للتصوير

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Detection of Linear Acceleration by the Maculae of Utricle and Saccule

- When the body suddenly accelerates forward, the statoconia fall backward with the hair cell cilia due to inertia.
Signal transmission increase giving a feeling of dysequilibrium (falling backward)
- This automatically causes the person to lean forward until the statoconia is shifted anteriorly exactly equals the backward fall and signals decrease back to normal
- At this point, the nervous system senses a state of proper equilibrium and no farther forward leaning occur
- When the person achieve constant running speed, signals return to normal and no dysequilibrium are felt
- Signaling occurs only at initial acceleration or at stopping

القدس للتصوير

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Detection of head rotation by the semicircular canals (Angular acceleration)

- When the head start to rotate in any direction (angular acceleration), the endolymph in the semicircular ducts, due to inertia, tends to remain stationary while the semicircular ducts turn, this causes relative fluid flow in the opposite direction
- The hairs cells bend to one side and their rate of discharge increases greatly
- With continued rotation, the discharge of the hair cell gradually subsides back to the resting level because the endolymph rotate in equal speed with the rotation of the canals
- When the rotation suddenly stops, the endolymph continues to rotate while the semicircular duct stops
- This time, the hair cells bends in the opposite direction, causing the hair cell to stop discharging entirely
- After few seconds, they gradually returns to its resting position and hair cell discharge return to its normal tonic level

The Predictive Function of the Semicircular Ducts

- If a person is running forward rapidly and then suddenly begins to turn to one side, the maculae will not sense that because they detect only linear acceleration so the person will feel imbalanced for a seconds
- But this do not occur because the semicircular ducts will detect head turning, and this inform the higher centers that the person will fall off balance within the next fraction of a second unless some correction is made
- By this the semicircular duct predicts that dysequilibrium is going to occur (predictive function)
- This function is performed in association with the cerebellum

Vestibular Mechanisms for Stabilizing the Eyes

- If the head rotate or lean in certain direction without concomitant rotation of the eyes, it will be impossible to fix the image on the retina (control eye gaze)
- Each time the head is suddenly rotated, signals from the semicircular ducts cause the eyes to rotate in a direction equal and opposite to the rotation of the head.
- This results from reflexes transmitted from the vestibular system to the oculomotor nuclei (third cranial nerve) that controls certain eye movements

Dose the vestibular apparatus alone is enough to detect disequilibrium??

- The vestibular apparatus alone is not enough because it detects only changes in head movements but not the entire body
- Other receptors are involved in maintaining equilibrium including:
 - 1- Neck proprioceptors
 - 2- Proprioceptors and Exteroceptors from other body parts
 - 3- Visual signals

Role of neck proprioceptors

- When the head only is leaned in one direction the neck proprioceptors send signals exactly opposite the signals transmitted from the vestibular apparatus so that the person **do not feel dysequilibrium**.
- But if the entire body leans in one direction, the impulses from the vestibular apparatus are not opposed by signals from the neck proprioceptors. In this case, the person **dose feel dysequilibrium** in the entire body

Role of Proprioceptive and Exteroceptive signals from other body parts

- Pressure sensations from the footpads send information about: weight distribution on the two feet
- Exteroceptive information is especially necessary for the maintenance of equilibrium when a person is **running**
(air pressure against the body signals that there is a force against oppose the gravity. The person leans forward to oppose this force and to maintain equilibrium)

Role of Visual informations

- After destruction of the vestibular apparatus, and proprioceptive informations one can use the visual mechanisms for maintaining equilibrium
- A linear or rotational movement of the body shifts the images on the retina, and this signals the equilibrium centers
- Normal equilibrium is maintained as long as the eyes are open and motions are performed slowly. Otherwise this ability will be lost

Vestibular disorders

- **Nystagmus** : involuntary rhythmic eye movements due to disturbed connection with cerebellum, oculomotor and reticular system
- **Vertigo** : feeling that the surrounding are spinning. Associated with nausea, vomiting and tinnitus
- **Motion sickness**: exaggerated response of vestibular system due to imbalanced information from the eyes, head proprioceptors and vestibular receptors
- **Meniere's syndrom**: attacks of vertigo, tinnitus and deafness. Results from increase endolymph in the canals

Physiology of the Nervous System

The Motor Nervous System

4) Role of the Basal Ganglia in Motor Control

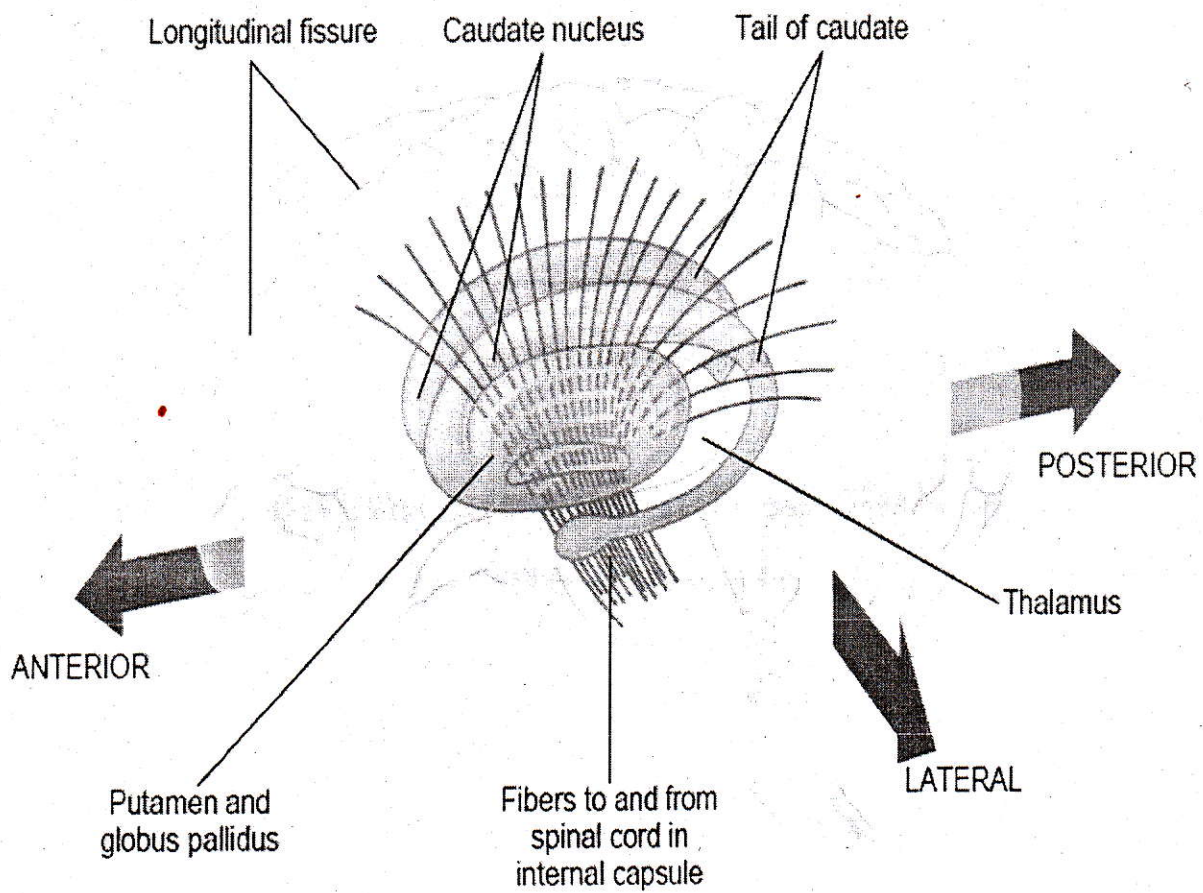
مركز القدس للخدمات الطلابية

1

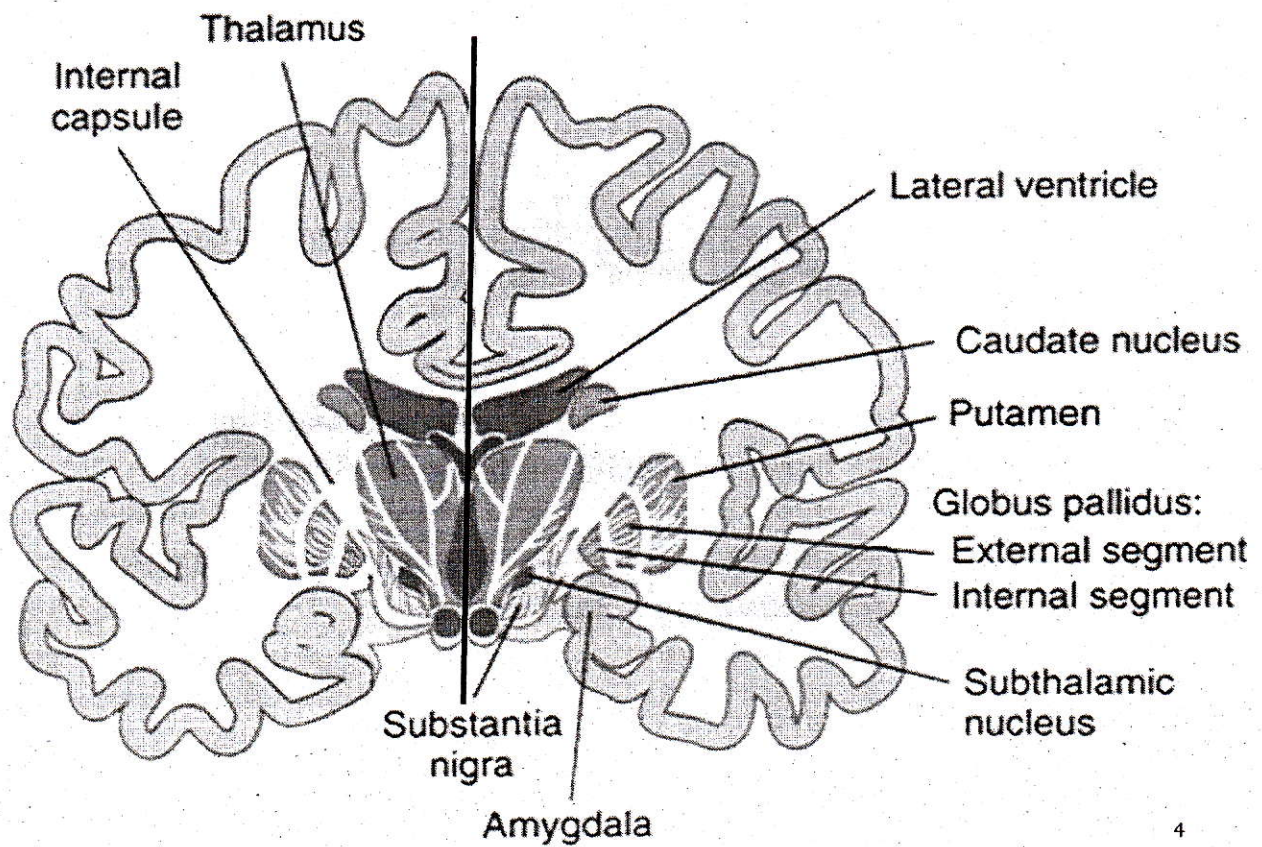
The Basal Ganglia

- Located deep in the cerebral material, lateral to and surrounding the thalamus on each side of the brain
- The basal ganglia consist of the group of nuclei: caudate, putamen, globus pallidus (internal and external parts), substantia nigra and subthalamic nuclei.
- Usually the putamen and caudate nuclei together are called the **striatum** considering that they functions together at the same time
- BG nuclei have extensive connections with almost all other sensory-motor structures and between each other
- BG have motor and cognitive functions

2



3



4

Motor Functions of the Basal Ganglia

- BG helps in motor planning so they prepare for motor actions by converting the intention into action
- BG control the complex patterns of muscle movement (writing, cutting paper with scissor, vocalization, eye movement) by controlling the sequencing of successive and parallel movements
- Help in the initiation of movements and correct the movements while in progress
- BG act as a brake to prevent unwanted movements
- Control muscle tone
- Control automatic associated movements (e.g. swing of hands during walking or facial expression during talking)

5

Cognitive Functions of the Basal Ganglia

- 1) The caudate nucleus plays major role in controlling the **cognitive control** of sequence motor activity.

(An example of this function is a person facing a lion. He will respond immediately and automatically by turning away and running

Without this functions, the person will think for too long to respond quickly and appropriately)

- 2) Control the relative intensity of the movements, this means: to determine how rapid and how large the movement will be

e.g: writing a letter (the rapidity of writing and size of the letter change but the proportions remains the same (this function done mainly with association area of the parietal cortex)

- 3) It plays a role in motivations, emotions (psyche) and memory due to caudate connections to the limbic system and association areas of the cortex
An example is the patient of Parkinson disease. Usually he has psychological disturbance in addition to motor problems

Also he walks in slow short steps but if a car is coming towards him he suddenly run away then again return to slow short steps

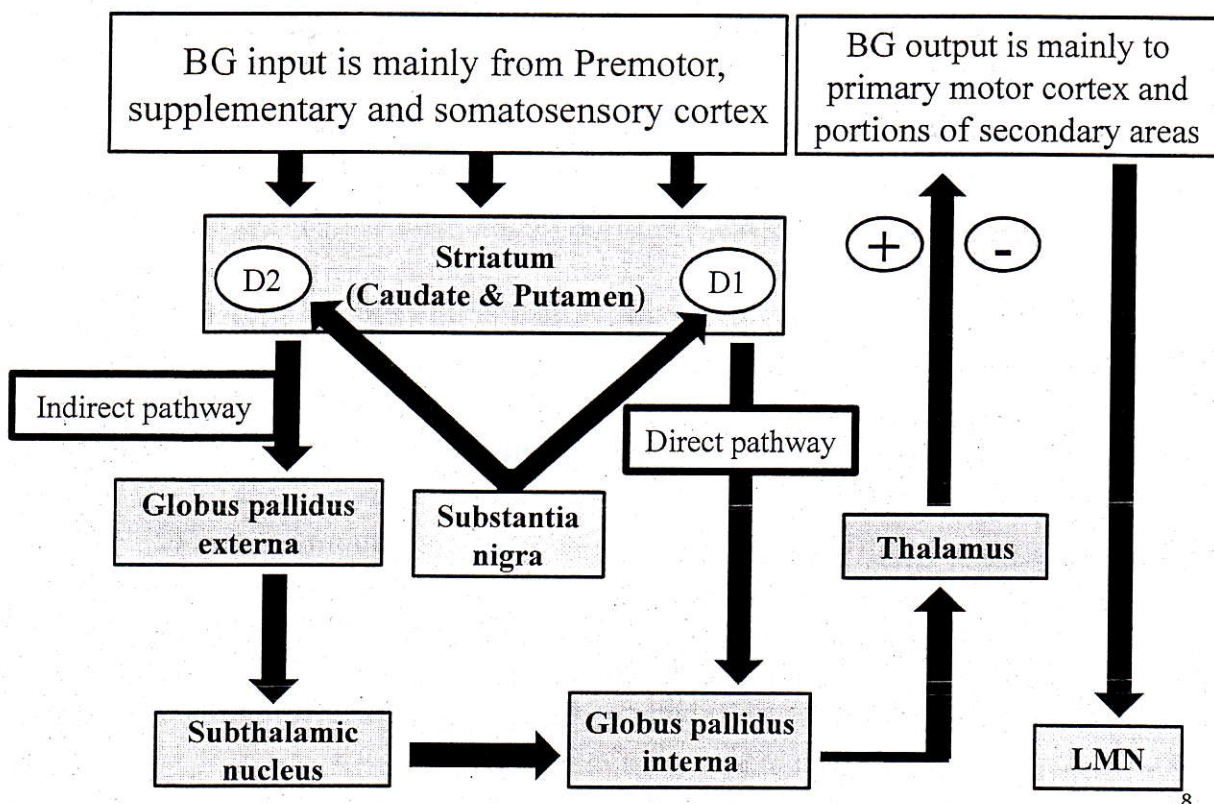
6

Neuronal circuits of the basal ganglia

- The basal ganglia nuclei has tremendous interconnections among themselves plus extensive input and output pathways with the other motor regions of the brain (motor cortex, thalamus, brain stem and cerebellum)
- The basal ganglia receive most of their input signals from the cerebral cortex itself and also return almost all their output signals back to the cortex
- Functionally basal ganglia connections form two major circuits or pathways, the **direct and indirect pathways**
- These two pathways oppose each other to allow certain movements and prevent other unwanted movements

7

BG Neuronal circuits



8

BG Neuronal circuits (continue)

- The direct and indirect pathways have opposite effects on motor activity
- In the direct pathway, striatum project directly to globus pallidus interna
The consequence of this pathway is to increase the excitatory drive from thalamus to cortex to allow the required movements
(Remember, the direct pathway turns up motor activity)
- In the indirect pathway striatum project indirectly to GP interna through subthalamic neuclus
The consequence is to decrease the excitatory drive from thalamus to cortex to inhibit unwanted movements
(Remember, indirect pathway turns down motor activity)
- In addition the caudate of the striatum send its output back to secondary motor areas rather than to primary cortex because it acts on cognitive part of the movements

9

Neurotransmitter Substances in the Basal Ganglia

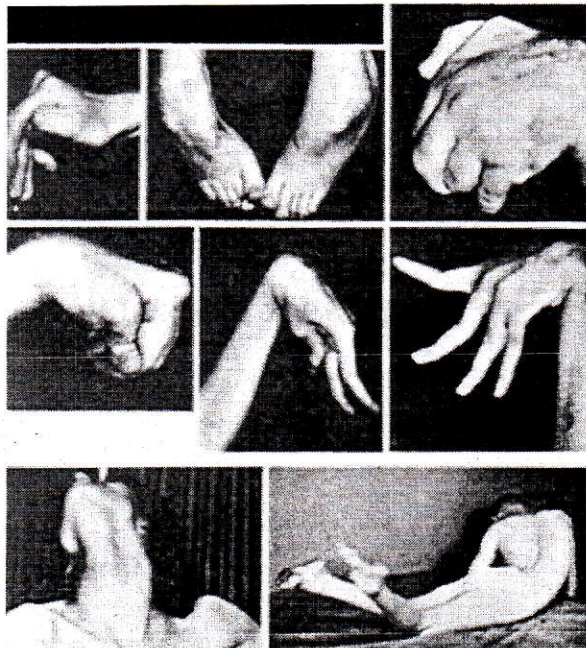
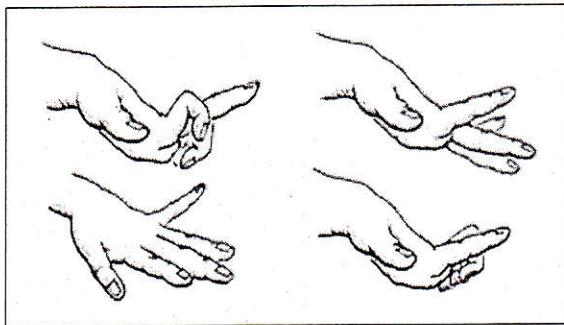
- The most important neurotransmitters involved in BG circuits are:
 - Glutamine : an excitatory transmitter
 - GABA : an inhibitory transmitter
 - Dopamine : an inhibitory transmitter

10

Basal Ganglia Lesions

- GB lesions might lead to suppression of some voluntary actions like initiation of movements (**hypokinesia**) and appearance of some other involuntary movements (**hyperkinesia**)
- Lesions in the **globus pallidus** frequently lead to spontaneous writhing movements of a hand and arm called **athetosis**
- **Dystonia** is a severe form of **athetosis** where the joints are locked in in one position for long time
- A lesion in the **subthalamus** often leads to sudden violent flailing movements of an entire limb, a condition called **hemiballismus**.
- Multiple small lesions in the **putamen** lead to dancing movements in the hands, face, and other parts of the body, called **Huntington chorea**.
- Lesions of the **substantia nigra** lead to the common and extremely severe disease of rigidity, akinesia, and tremors known as **Parkinson's disease** 11

Athetosis

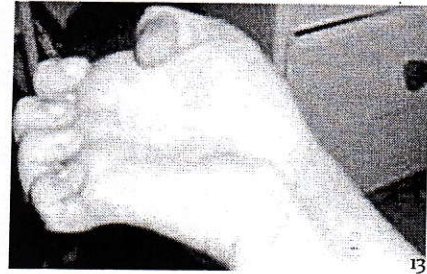
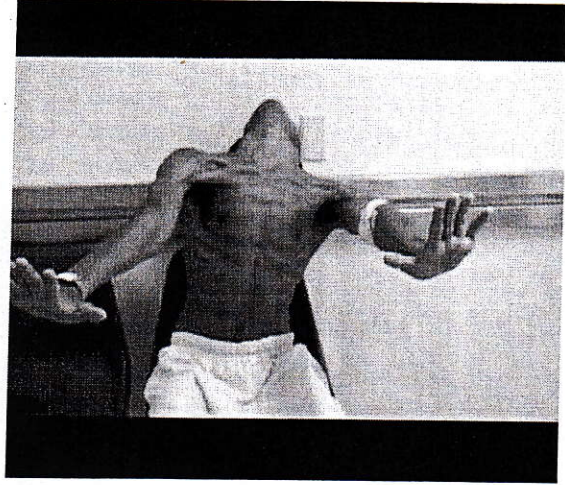


Dystonia sever form of athetosis



FIG. 2 Blepharospasm and spasm of jaw closure and mouthretrusion in a 51 year old lady with symptoms for three years.

FIG. 3 Spasm of jaw opening and mouth retraction in a 65 year old lady with symptoms for four years.

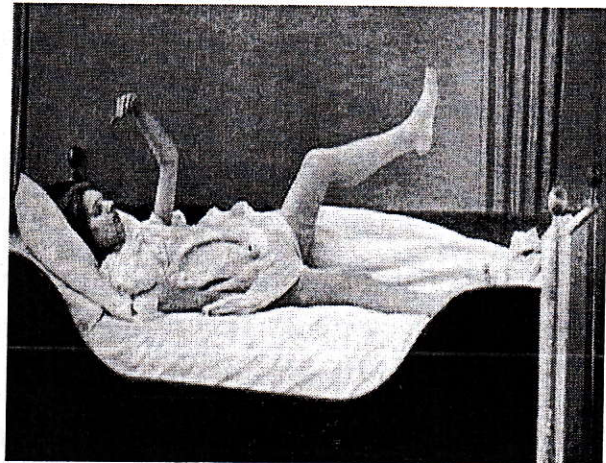


13



From an illustration

Chorea

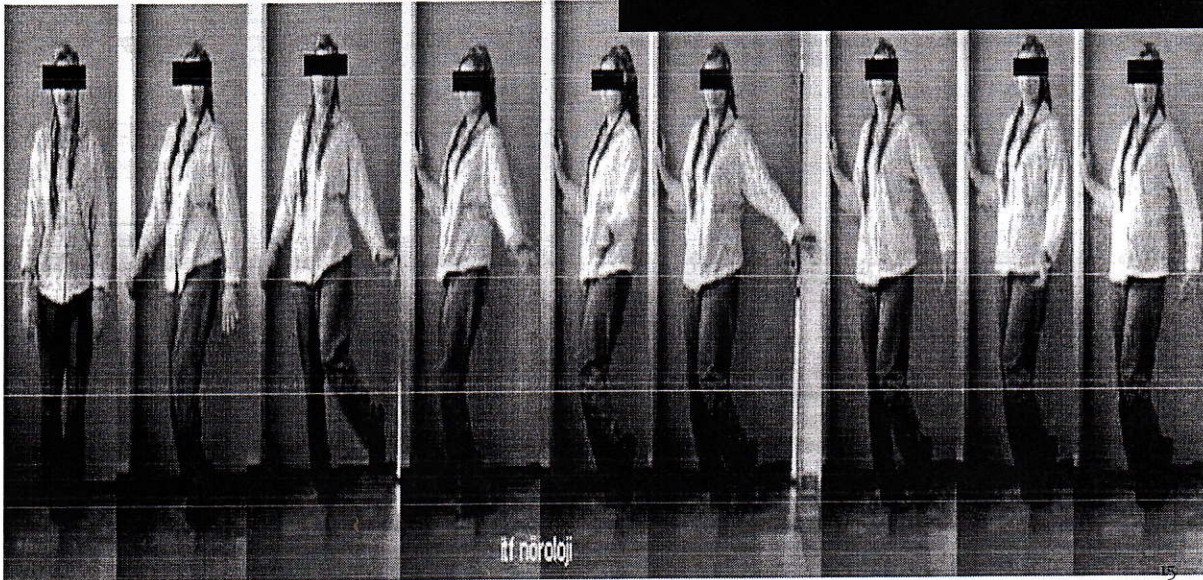
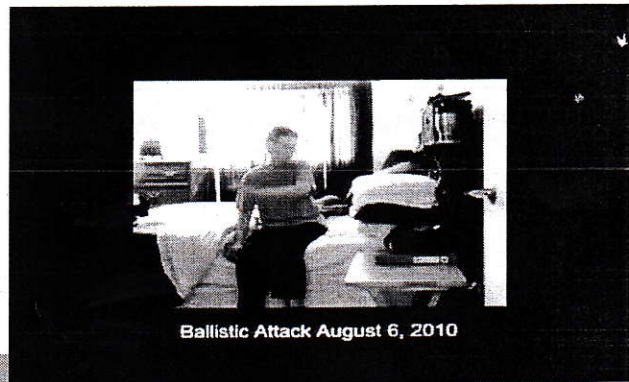


داء الرقص

sehha.com

تختلف حركات داء الرقص في شدتها بداية من حركات عدم الارتياح . إلى حركات الأيدي المزعجة للأخرين . إلى مشية غير ثابتة تشبه الرقص . إلى تدفق مستمر من الحركات الشديدة المسببة للإعاقة

Hemiballismus



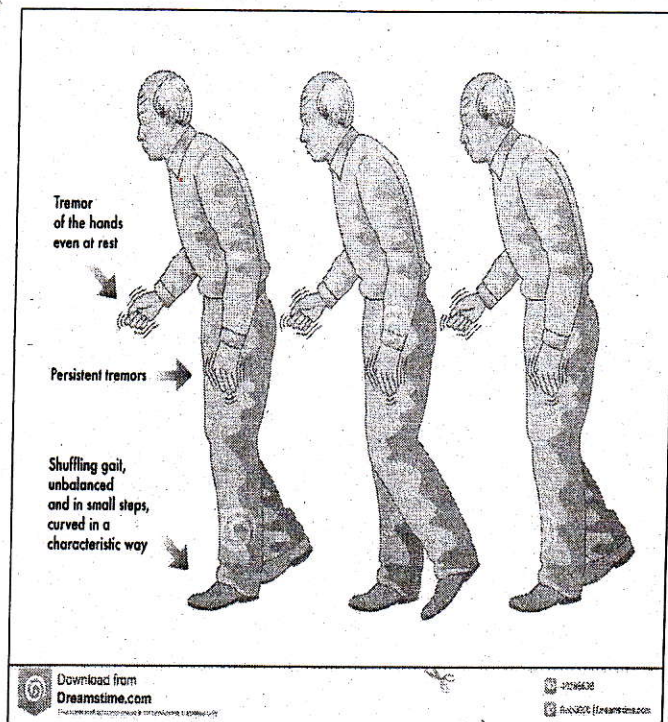
Parkinson's disease

Results from degeneration of substantia nigra and loss of dopamine.

The disease is characterized by:

- 1) Rigidity of much of the musculature of the body
- 2) Hypertonia
- 3) Involuntary tremor even when the person is resting (pill rolling movements of fingers, tremor of hand and head)
- 4) Serious difficulty in initiating movement (akinesia) lead to loss of facial expression, decrease in spontaneous movements like blinking swinging of arms during walking
- 5) Defective posture (stooping forward) with defective righting from supine or sitting to standing position
- 6) Walking in small slow steps (shuffling gait)

Parkinson's disease



Catherine Mitzger
13 Octobre 1869

Physiology of the Nervous System

The Motor Nervous System

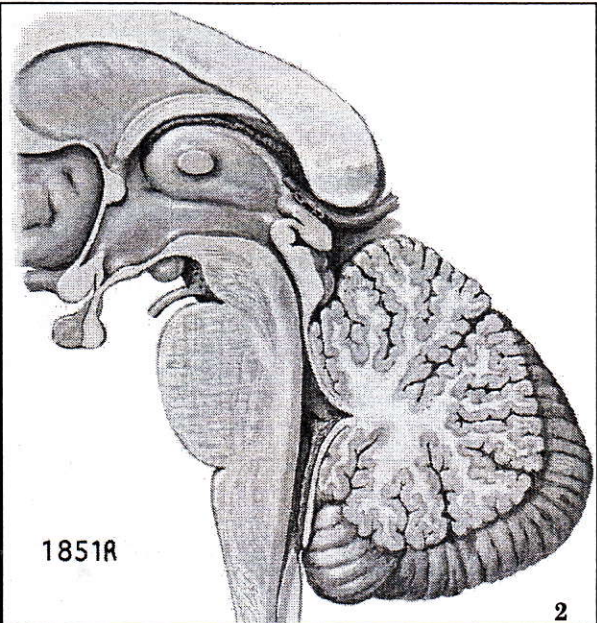
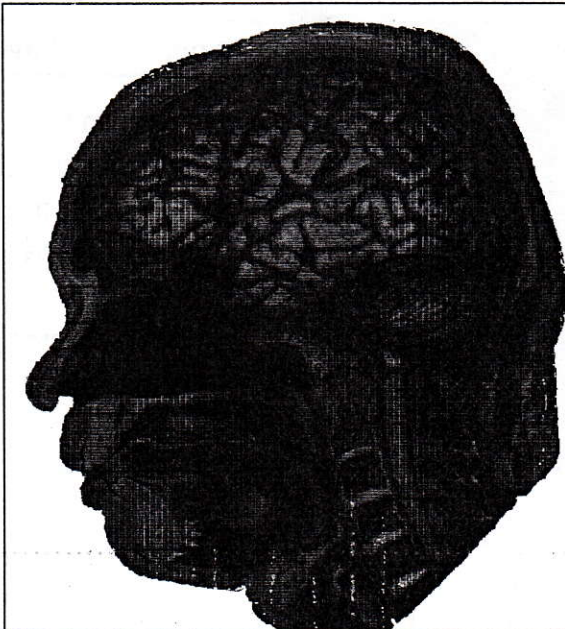
5) Role of the Cerebellum in Motor Control

1

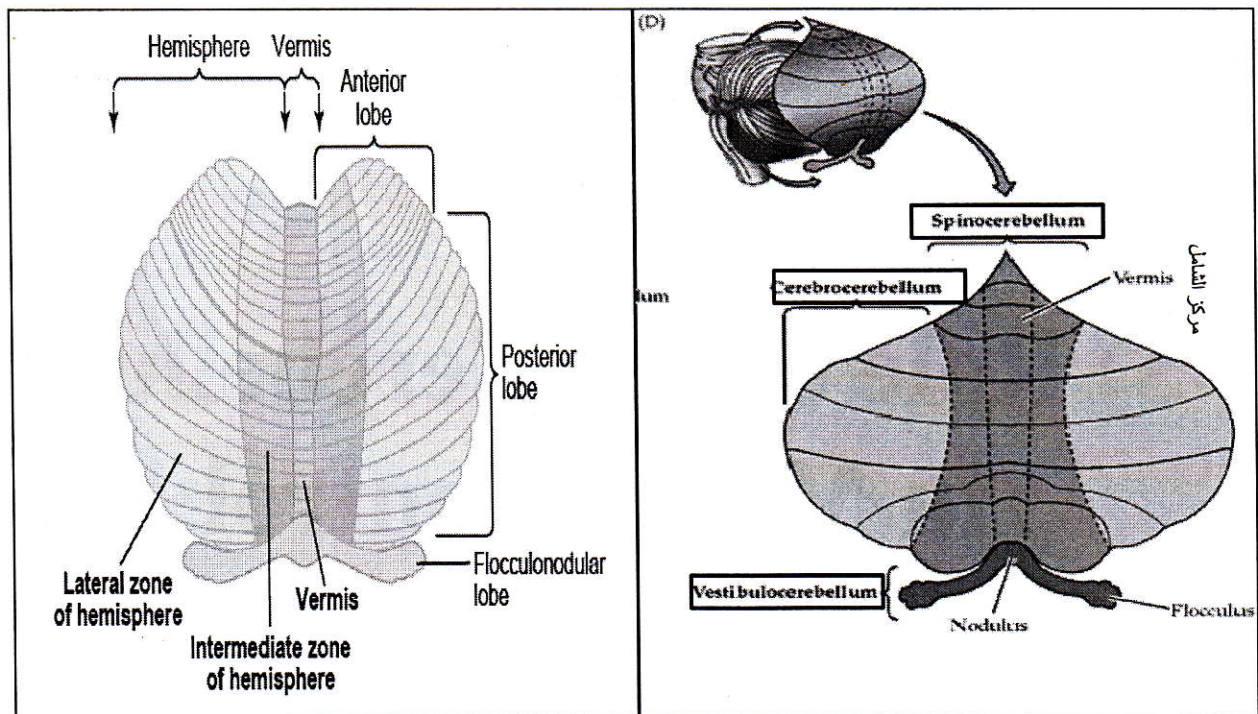
مركز الشامل

The Cerebellum

مركز الشامل

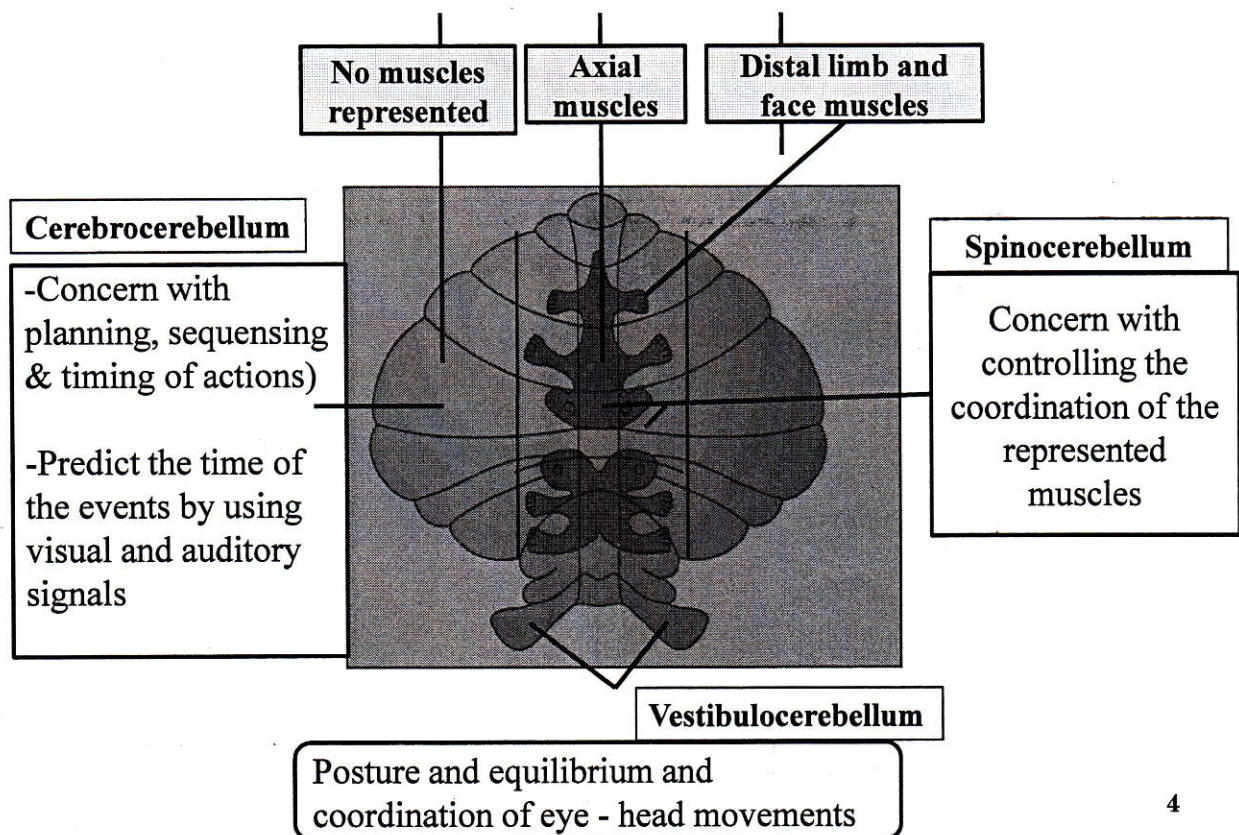


2



Anatomical divisions

Functional divisions



Functions of the Cerebellum

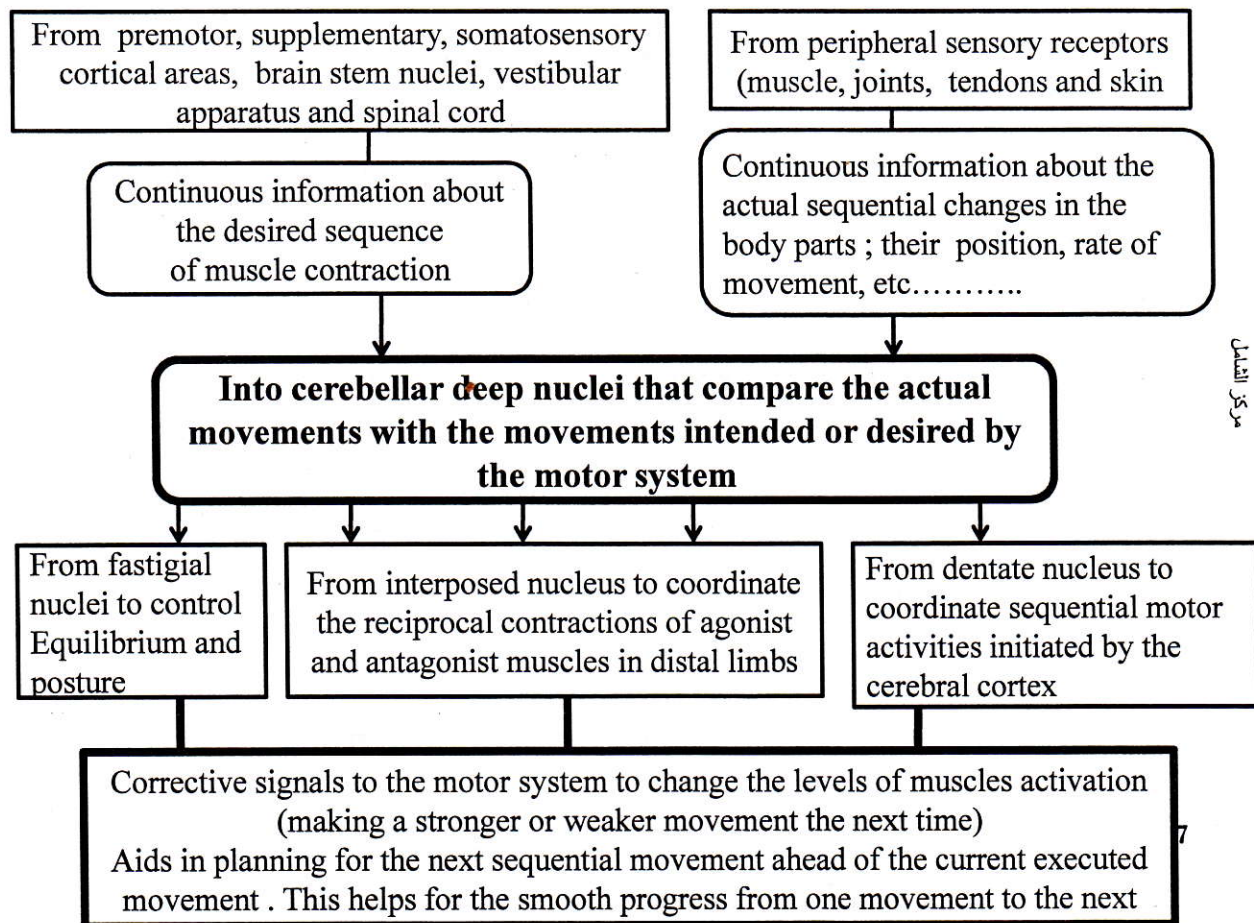
- The cerebellum plays major roles in the **coordination** of motor actions. this includes:
 - 1- Timing for motor activities (determines when to stop)
 - 2- Insuring rapid, smooth progression from one movement to the next.
 - 3- Adjust the intensity of muscle contraction according to the load
 - 4- Control the interplay between agonist and antagonist muscle groups
 - 5- Helps to sequence and correct motor activities while ongoing to match the required actions
- Cerebellum is especially important for rapid movements
- The ablation of the cerebellum do not cause muscle paralysis

5

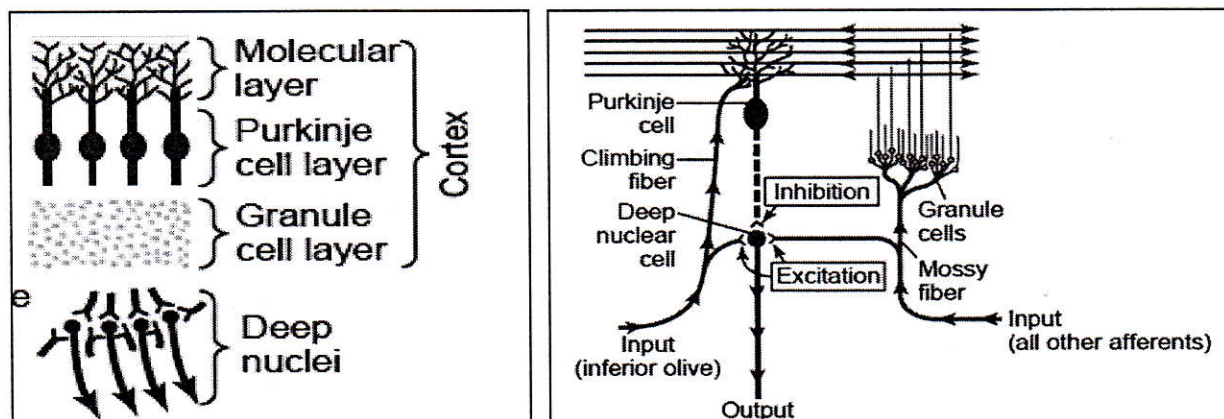
Neuronal Circuit of the Cerebellum

- Each time an input signal arrives in the cerebellum, it goes into one of the cerebellar deep nuclei
- There are three deep nuclei in the cerebellum that makes three circuits:
 - The **Fastigial nuclei** (in the vermis) send their output into pons and medullary nuclei to control posture and equilibrium
 - The **Interposed nuclei** (intermediate zone) send their output into thalamus and then to cerebral cortex, mid brain red nucleus and basal ganglia to coordinate agonist and antagonist muscles of distal limbs
 - The **Dentate nuclei** (lateral hemisphere) send their output into thalamus and finally to cerebral cortex to coordinate sequential motor activities initiated by the cerebral cortex (planning)

6



The functional unit of the Neuronal Circuit of the Cerebellum



There is 30 million functional units in the cerebellum

Each unit composed of **purkinje cell** in cerebellar cortex and a **nuclear cell**

The nuclear cells excited by two sensory fibers; Climbing fiber from the medulla and Mossy fibers from all other sources

At the same time, the Climbing fiber stimulate the purkinje cell

Mossy fibers also stimulate purkinje cell but indirectly through interneurons

When the purkinje cells is stimulated they inhibit the nuclear cells

The functional unit of the Neuronal Circuit of the Cerebellum

The sensory inputs to nuclear cell inform the cerebellum about the condition of body muscles

Then, nuclear cell output goes to the muscles to change and correct the muscle action

The signals are reciprocal to agonist and antagonist muscles

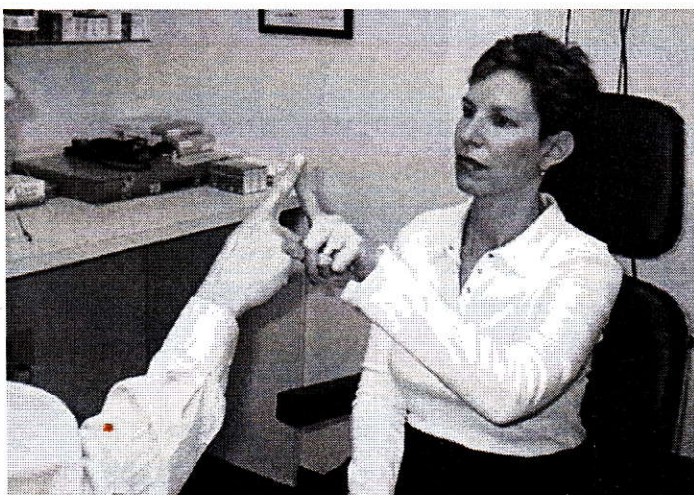
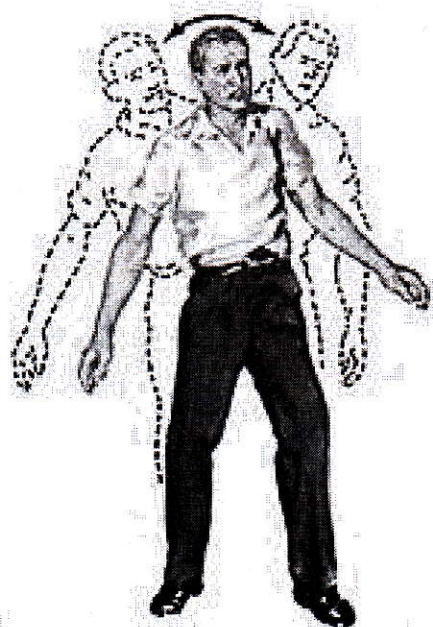
The inhibitory signals of purkije cell prevent the overshoot of muscle action

Example:

- When a person performs a new movement for the first time, feedback signals from the peripheral receptors will inform the cerebellum how much the actual movement fails to match the intended movement
- The climbing fiber signals to Purkinje cells lead to change the rate of discharge of purkinje cell and change rate of inhibition on nuclear cell
- This changes the timing and other aspects of movements to correct the action to become perfect
- When the person learn to make the action perfectly, the climbing fibers no longer need to send this "error" signals to the cerebellum

The effect of Cerebellar lesions

- Cerebral lesions in its full picture causes incoordination of movements called **cerebellar ataxia**
- Ataxia includes the following:
 - 1) Dysmetria: failure to reach the object, either because of miss direction (**past pointing**) or inability to stop at proper time (**overshoot**)
 - 2) Abnormal posture (tend to fall to one side while standing)
 - 3) Abnormal gait (wide based, swing to one side) called drunken gait
 - 4) Inability to perform rapid alternative movements (defect in control timing between agonist antagonist muscles)
 - 5) Cerebellar nystagmus
 - 6) Dysarthria (explosive broken speech)
 - 7) Intension or action tremor (appear with movement and disappear at rest)
 - 8) Hypotonia
- Lesions to any division of cerebellum result in impairments on **ipsilateral side** of the body





5(2)-The cerebral cortex

Intellectual Functions of the Brain:

Learning and Memory

مركز الشامل

مركز الشامل

1

- All areas of the cerebral cortex have extensive efferent and afferent connections with deeper structures of the brain
- Especially important for intellectual functions are the association areas of the cortex
- The association areas receive and analyze signals simultaneously from multiple regions of both the motor and sensory cortices and from subcortical structures.
- There are three major association areas:

1- Parieto-occipito-temporal Association Area

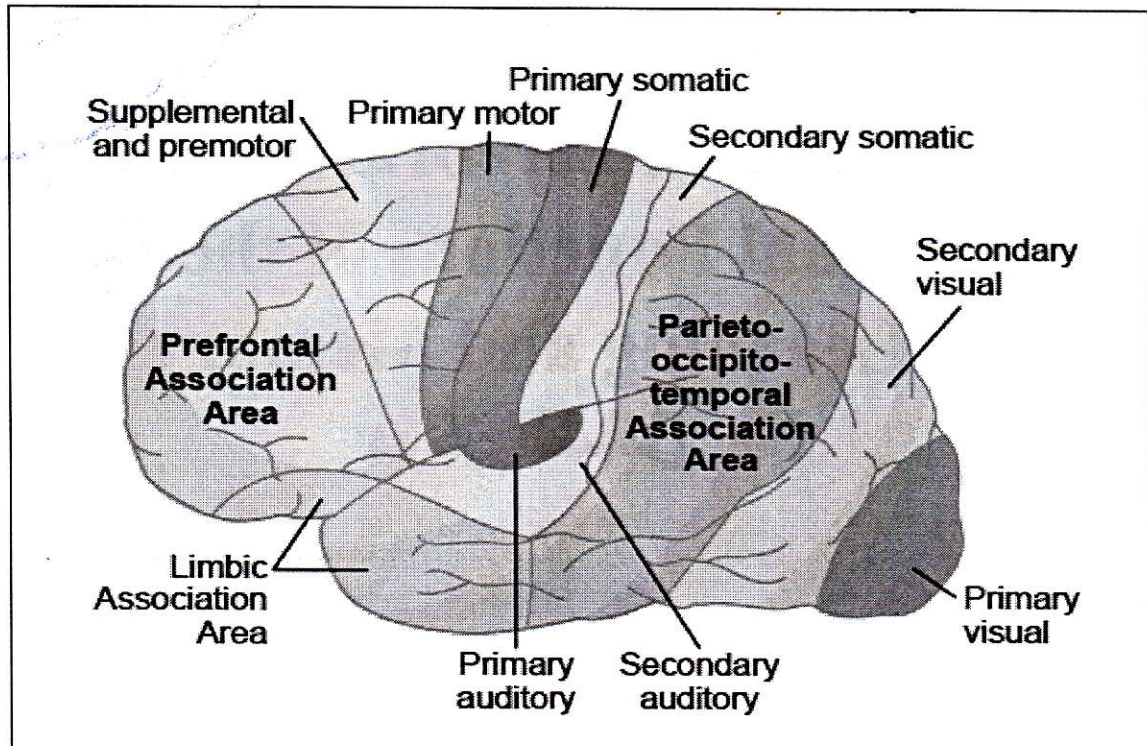
2- Prefrontal Association Area

3- Limbic Association Area

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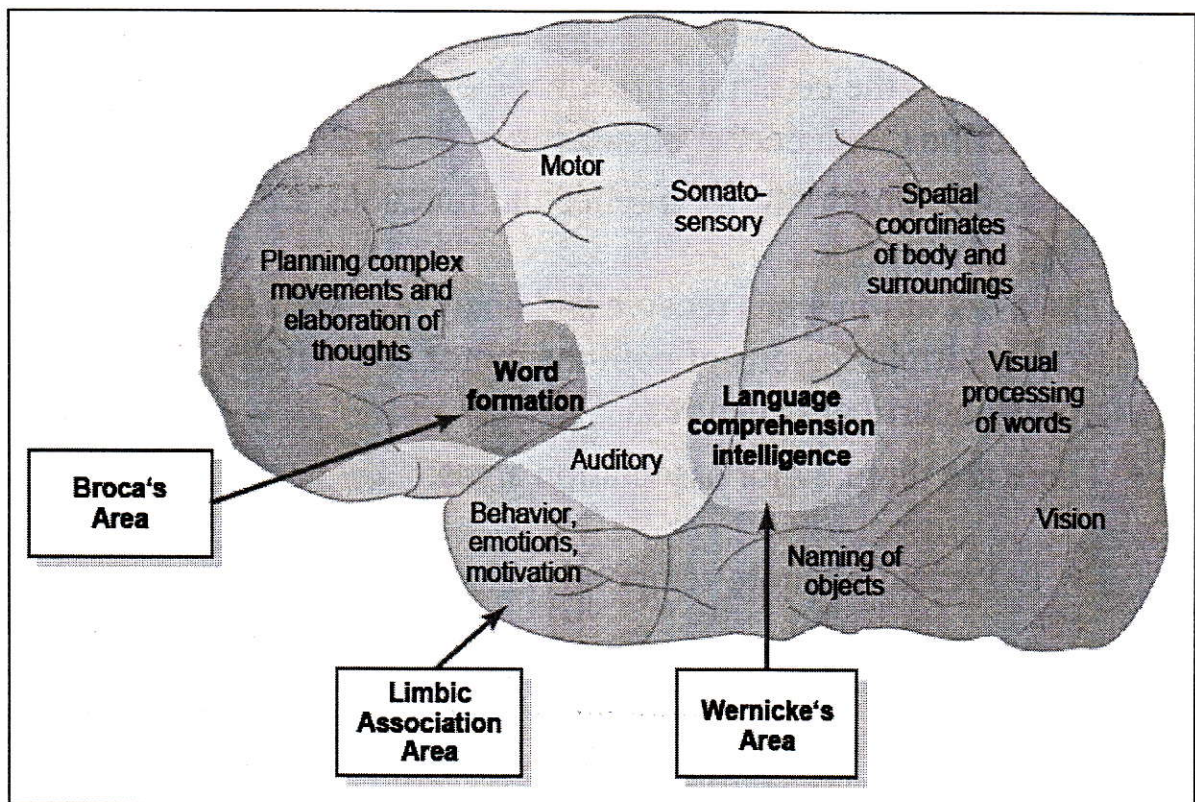
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The Cortical Association Areas



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Parieto-occipito-temporal Association Area

- **Contains four functional areas:**

- 1) Area for analysis of the spatial orientation of the Body:**

Functions in continuous analysis of the spatial relation of all body parts to each other and to the surroundings

- 2) Area for Language Comprehension (Wernicke's area):**

The most important region for higher intellectual function because such intellectual functions are language based

- 3) Area for Initial Processing of Visual Language (Reading):**

This area is needed to make meaning for the perceived words.

- 4) Area for Naming Objects:**

The names are learned mainly through auditory input, while the physical natures of the objects are learned mainly through visual input. So this area works with visual ,auditory and Wernicke's areas

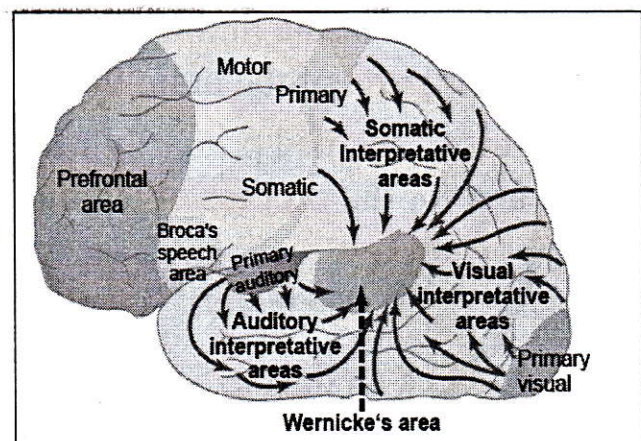
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Comprehensive Interpretative Function of Wernicke's Area

- It is also called the area of intelligence and **general interpretative area**

- A person with severe damage in this area can see well and recognize words but unable to arrange them into a coherent thought and do not the meaning behind them



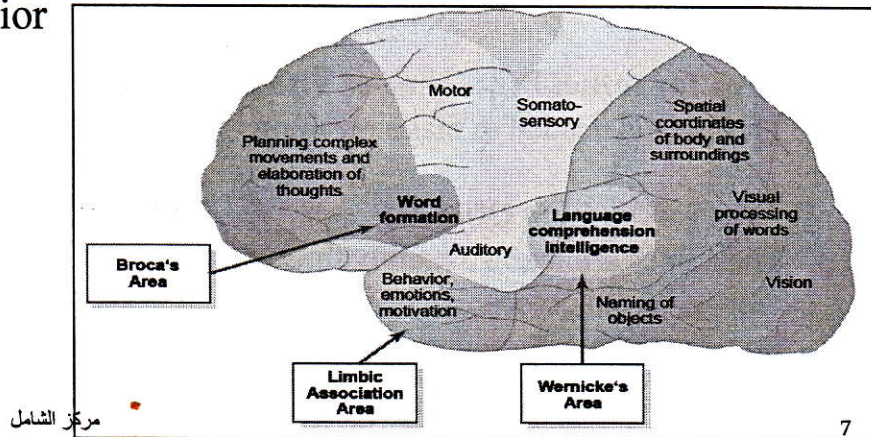
- Electrical stimulation in Wernicke's area of a conscious person causes a highly complex thoughts like visual scenes or auditory hallucinations such as musical piece, or a statement made by someone

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Prefrontal Association Area

- Contains areas for 4 important functions:
 - 1) Planning of sequential complex movements
 - 2) Thought elaboration
 - 3) Storage of short memory (working memory)
 - 4) Word formation (Broca's area)
 - 5) Social behavior



Limbic Association Area

- This area is found in the anterior pole of the temporal lobe, medial portion of the frontal lobe and in the cingulate gyrus
- It is part of the limbic system which is a complex circuit involve other parts of the brain
- It is concerned primarily with behavior, emotions, and motivation and for the process of learning

Area for Recognition of Faces

- An area on the medial basal surface of occipital lobes and part of medial surfaces of the temporal lobes
- Damage in this area results in inability to recognize faces called (proso-phenosia)
- This area is in connection with visual cortex and with limbic system

The Concept Of Dominant Hemisphere

- The general, **Wernicke's area, angular gyrus, the speech and motor control areas**, are usually much more highly developed in one cerebral hemisphere than in the other.
- This hemisphere is called the dominant hemisphere
- In about 95% of all people, the left hemisphere is the dominant one
- Although these areas are usually highly developed in only the left hemisphere, these areas receive sensory information from both hemispheres and are capable also of controlling motor activities in both hemispheres
- Fiber pathways in the corpus callosum used for communication between the two hemispheres
- Studies indicate that each cerebral hemisphere is specialized for certain functions

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Specialized functions of Hemispheres

Dominant (left) hemisphere	Non dominant (right) hemisphere
Categorical hemisphere Reasonable hemisphere	Representational hemisphere Emotional hemisphere
Classification , symbolization , sequential analysis.	Spatial orientation , recognition (of faces or objects, musical peace)
Solving problem requires stepwise logical solutions . e.g. mathematics	solving problems based on recognition e.g. the puzzle
Production of spoken and written speech (Verbal communication)	Nonverbal communication
Example : a split brain man. A picture of an object is presented to the right visual field, it will perceive it by left hemisphere. The man can describe the object verbally Presented to left visual field, perceived by right hemisphere he cannot describe it verbally but he can pick it out from many objects	

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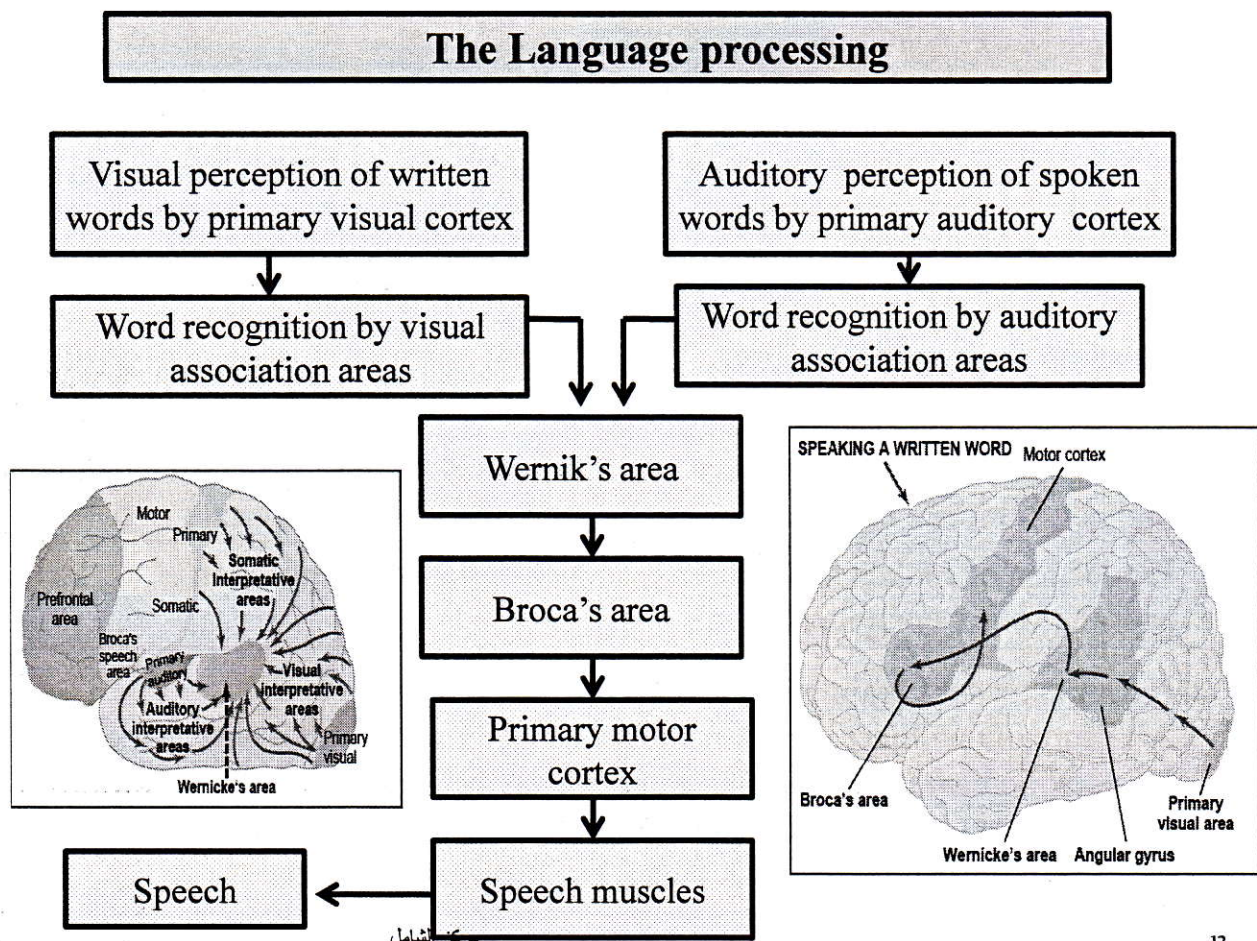
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Language Processing in the Brain

- **There are two aspects of verbal communication (language):**
- **Sensory aspect (language input):** involving the ears and eyes
 - From ears goes to auditory association area to understand the spoken words
 - From eyes goes to visual association area to understand the written words
 - From there signals sent to the general interpretative area (Wernick's area), where the signal is interpreted into clear thought.
- **Motor aspect (language output):** involving vocalization and its control.
 - From Wernick's area, the thought is sent to Broca's area that converts the thought into verbal expression by programming the suitable movements for this expression
 - From there the orders are sent to primary motor cortex then to the muscles of speech

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Speech disorders

- **Word blindness or word deafness (sensory aphasia):** lesion in visual or auditory association areas cause non understanding of word meaning
- **Wernicke's Aphasia (sensory aphasia) :** the patient understands the words but are unable to interpret the thoughts behind them. He can talk but a meaningless speech
- **Motor Aphasia:** the patient is able to decide what he wants to say but cannot emit proper words, instead, he just emit noises. This results from damage to Broca's area
- **Global aphasia :** the patient neither understand nor express the words. This results from extensive brain damage
- **Dysarthria :** difficulty in pronunciation due to muscle articulation defects. The lesion can be in primary motor cortex or its pathway to muscles, cerebellum or basal ganglia

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Learning and Memory

- Learning is the acquisition of new information
- Memory is the storage and recall of learned information
- Memory is formed by changing the sensitivity of synaptic transmission between neurons as a result of previous repetitive neural activity
- Memory formation can occur at all levels of the nervous system including the spinal cord
- The brain store the important information as memory by facilitating the synaptic transmission (this is called **sensitization**)
- The brain ignore the non important information by inhibiting the synaptic transmission (this is called **habituation**)

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Classification of Memories

- Memories are classified into:

- 1) **short-term memory:** (also called working memory) includes memories that last for seconds or minutes unless they are converted into long-term memories
- 2) **intermediate long-term memories:** which last for days to weeks but then fade away
- 3) **long-term memory,** which, can be recalled up to years or even a lifetime later

- **Other classification:**

- 1) Declarative memory (for events time and place, statements, experiences..etc)
- 2) Skill memory (how to do the things)

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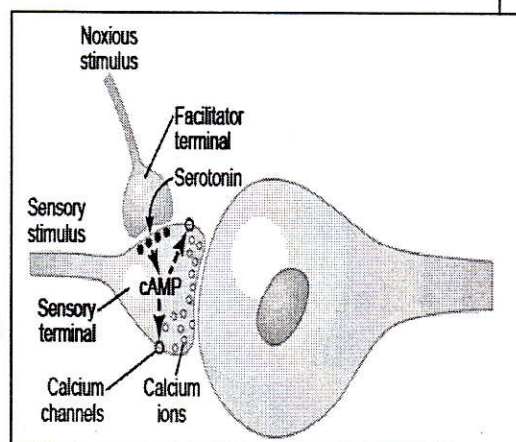
- **The mechanism of short term memory:**

- 1) Reverberation neuronal circuits
- 2) Pre-synaptic facilitation by neurotransmitters

- Both mechanisms increase entry of C^{++} ions into nerve terminal and increase transmitter secretion
- Example remembering some numbers

- **The mechanism of Intermediate Long-Term Memory:**

- Result from temporary chemical or physical changes, or both, in either the presynaptic or the postsynaptic membrane
- These changes result from stimulation of **facilitatory nerve fibers** that cause prolong action potential and finally leads to C^{++} ions entry...etc



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- **Mechanism of long term memory:**

- Result from actual structural changes at the synapses, that enhance or suppress signal conduction
- The structural changes include:
 1. Increase in number of transmitter vesicles and the sites of their release
 2. Increase in number of presynaptic terminals
 3. Changes in structures of the dendrites to permit transmission of stronger signals.
 4. Increase in number of neuronal connections (use it or lose it)

- **Memory consolidation:**

Is the conversion of short and intermediate memories into long term ones
This is achieved by inducing structural changes in the synapse through repetition (**rehearsal phenomenon**)

The time required is 10 minute for minimal consolidation and 1 hour for strong consolidation

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Role of Hippocampus in memory storage

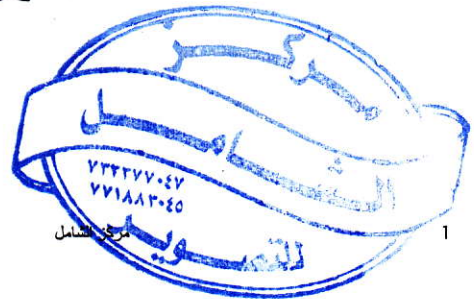
- Memories are stored in almost everywhere in the brain
- Of special importance is the hippocampus in medial side of temporal lobe
- Its role in memory storing is evident following its removal where the patients develop **anterograde amnesia**
- Those patients can remember the events before the removal of hippocampus but failed to remember the new events following the removal
- The new memories are short term type
- **Retrograde amnesia:** is failure to recall memories from the past. It is more severe for the recent memories
- It occurs mainly in lesions of the thalamus. But also in some hippocampal and cortical lesions

Learning

- Memory storage is part of learning process. Many areas involved in learning. Limbic system is an important one
- Learning is classified into:
 - 1) **Simple (non associative) learning:** use the same mechanisms of memory (facilitation or habituation of synapse)
 - 2) **Associative learning:**
involve establishment of relationship between two events. It includes:
 - a- Classical conditioning: learn to respond to stimuli that do not naturally cause the response
e.g. Giving food to a dog and ringing a bell at the same time.
 - b- Instrumental conditioning: learn to respond by reward and punishment. e.g. pressing different color buttons and experiencing pain or pleasure

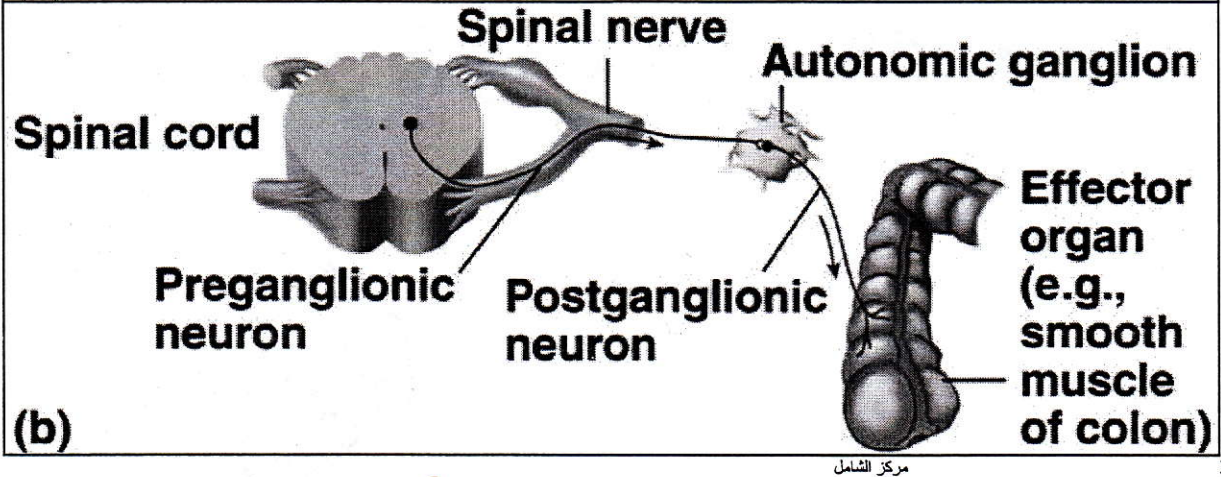
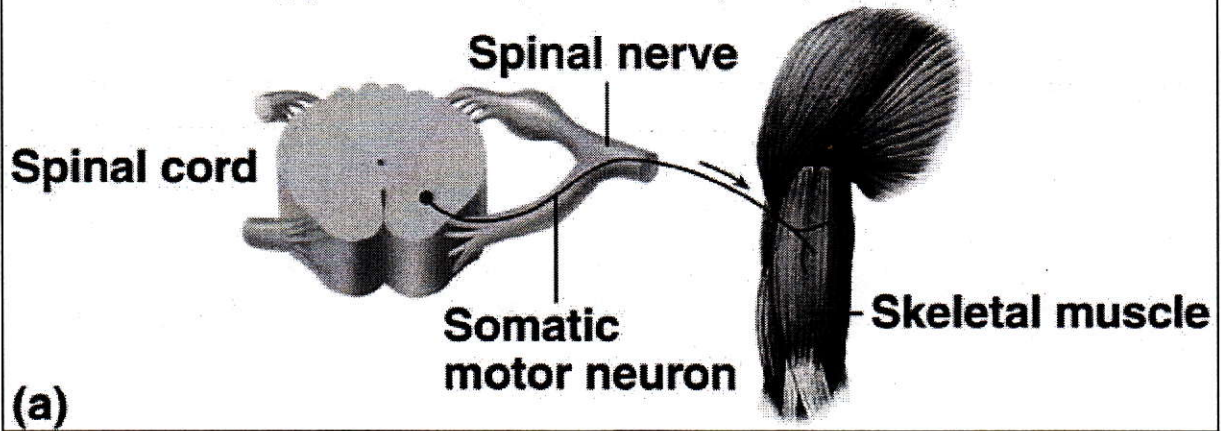
(6) The Autonomic Nervous System

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The Autonomic Nervous System

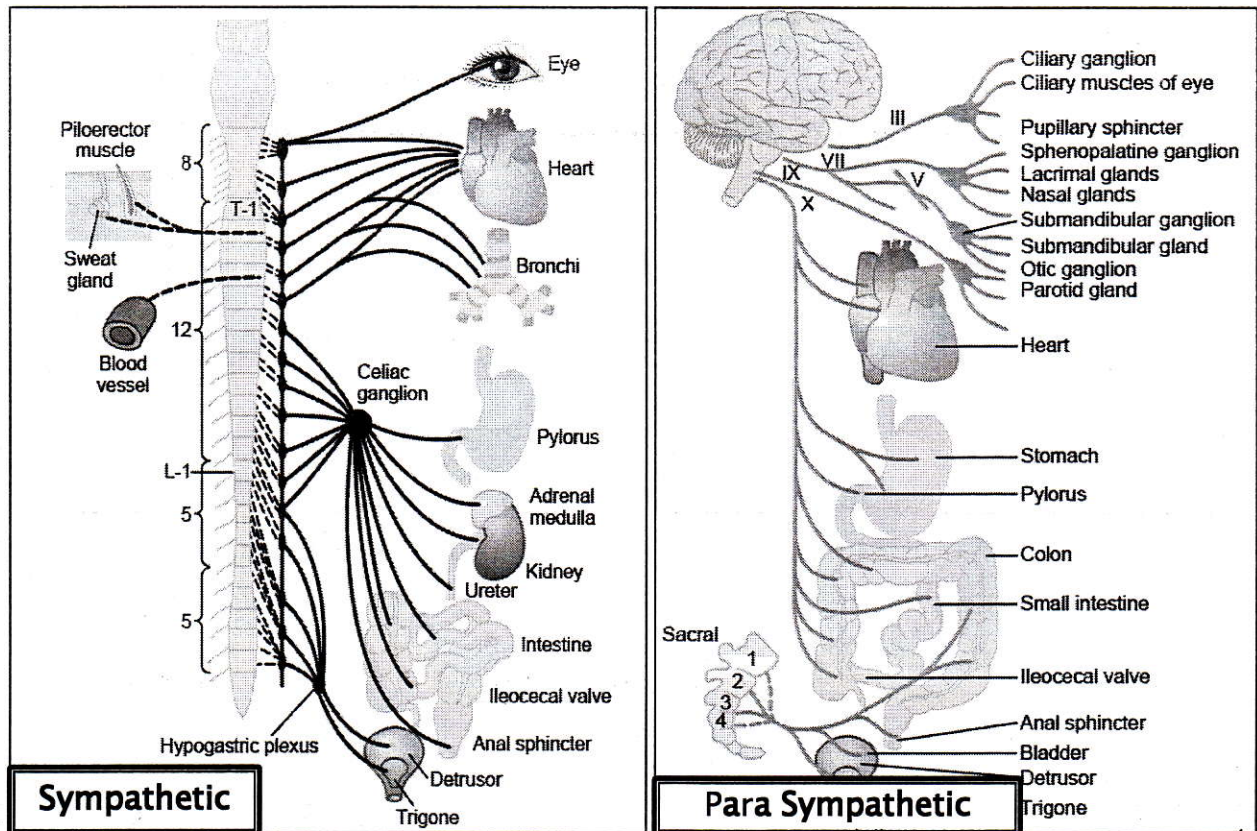
- ▶ The autonomic nervous system is the part of peripheral nervous system efferents that controls the visceral functions
- ▶ It characterized by rapid and intense actions
- ▶ It often operates by means of visceral reflexes at the subconscious level
- ▶ The efferent signals are transmitted to the organs of the body through two major subdivisions: The sympathetic and the parasympathetic nervous systems



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Physiologic anatomy of autonomic NS



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Physiologic anatomy of autonomic NS

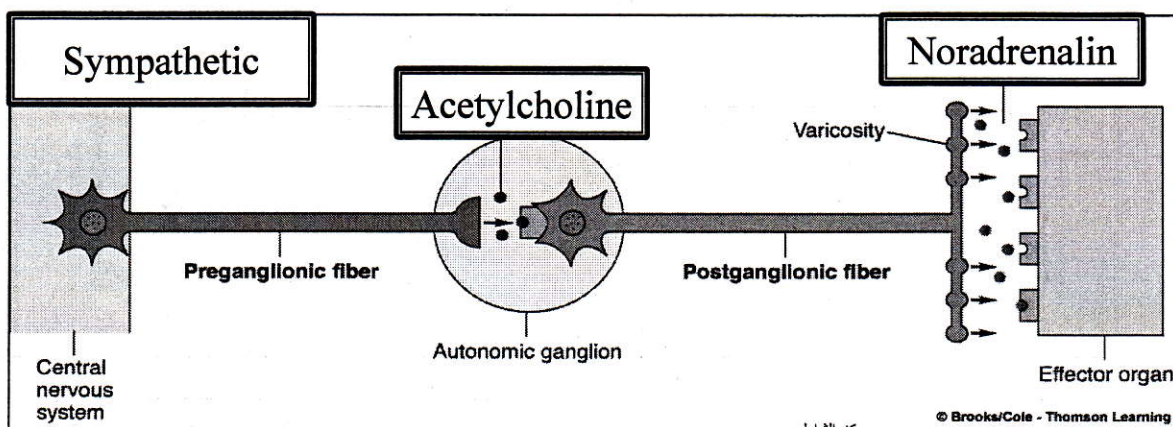
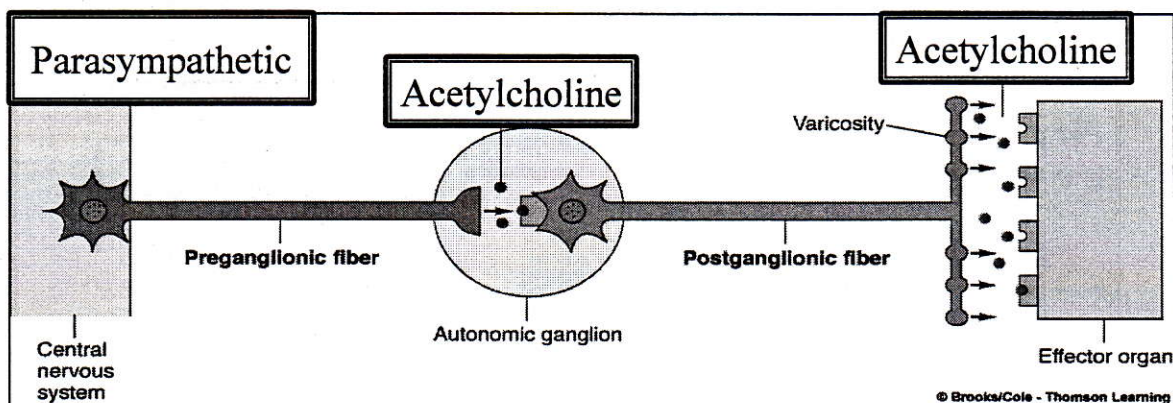
The sympathetic division:

- ▶ The efferent fibers (pre-ganglionic fibers) leave the cord and enter the para-vertebral chain ganglia
- ▶ Then the post-ganglionic fibers leave the ganglia and go directly to the organs or re-enter to one of pre-vertebral ganglia before leaving to the organs
- ▶ Innervations to adrenal medulla lead to secretion of epinephrine and norepinephrine which are the same transmitters of the sympathetic fibers

The parasympathetic division: efferent fibers leave through:

- ▶ Cranial nerves III, VII, IX, X. (X is the (vagus N.) supply most of the viscera
- ▶ Sacral segments of the cord supplies lower colon and the bladder
- ▶ The preganglionic fibers go directly to the organ wall where they synapse with the post-ganglionic fibers that supply the organ

Neurotransmitters of autonomic nervous system



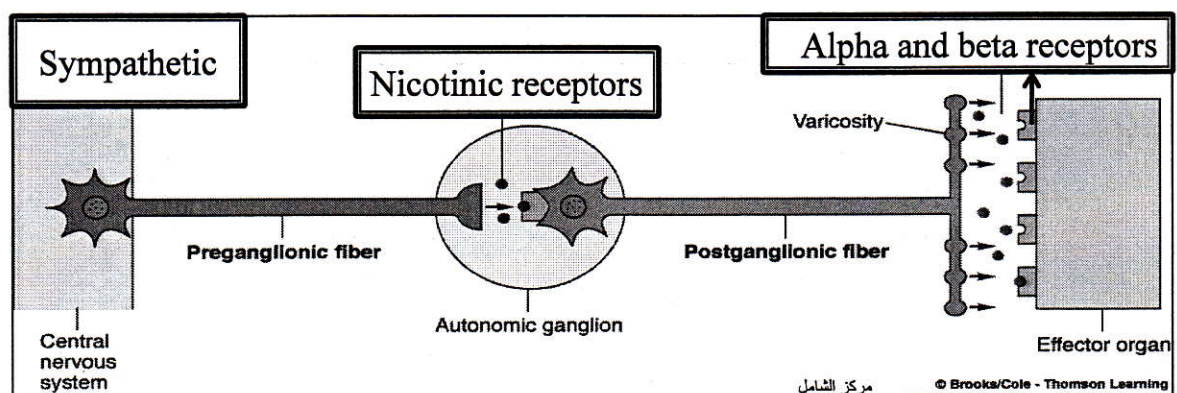
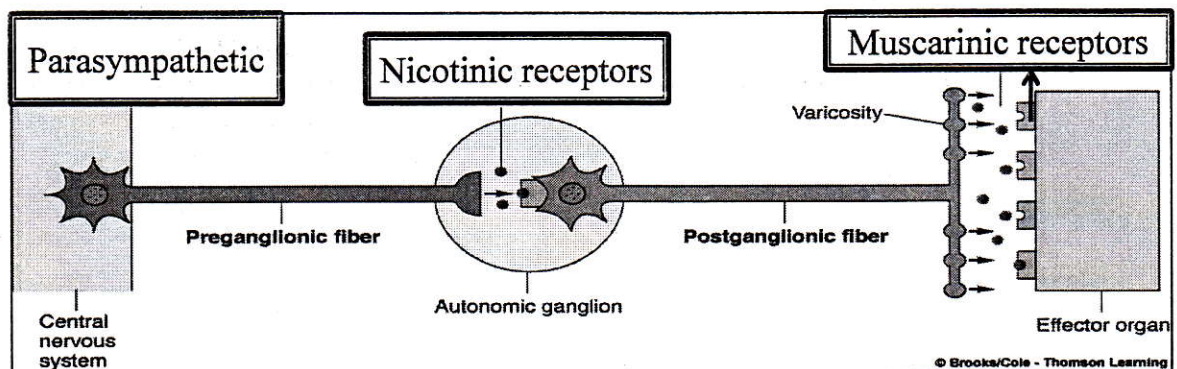
Neurotransmitters of autonomic nervous system

- ▶ The autonomic nerve fibers secrete one of two transmitters:
 - Acetylcholine (cholinergic fibers)
 - Norepinephrine, also called noradrenalin (adrenergic fibers)
- ▶ All preganglionic neurons are cholinergic in both autonomic divisions
- ▶ Their acetylcholine excite the postganglionic neurons
- ▶ All postganglionic neurons of the parasympathetic are cholinergic.
- ▶ Most postganglionic sympathetic neurons are adrenergic. With some exceptions to the sweat glands, piloerector muscles of the hairs and to a very few blood vessels which are cholinergic

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Receptors of autonomic nervous system



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Receptors of autonomic nervous system

- ▶ **Acetylcholine** receptors are two: muscarinic and nicotinic receptors
- ▶ The nicotinic receptors are found on postganglionic neuron at the ganglia (both sympathetic and parasympathetic divisions)
- ▶ The muscarinic receptors are on the effector organs
- ▶ **Noradrenalin** receptors are two: alpha receptors (alpha 1 and 2) and beta receptors (beta 1 and 2) on the effector organs
- ▶ Norepinephrine excites alpha receptors and to lesser extent beta receptors
- ▶ Epinephrin from adrenal gland excites both receptors equally

Characteristics of sympathetic and parasympathetic function

- ▶ Sympathetic stimulation causes excitatory effects in some organs and inhibitory effects in others. The same thing also applied to parasympathetic system
- ▶ In the organ that supplied with both systems, the two systems act reciprocally to each other (opposing each other)
- ▶ But most organs are dominantly controlled by one of the two systems
- ▶ **Give examples of these effects in the heart, blood vessels and in eye pupils**

Special importance of adrenal medulla secretions

- ▶ Stimulation of the sympathetic nerves to the adrenal medullae causes large quantities of epinephrine and norepinephrine to be released into the circulating blood and carried to all tissues of the body.
- ▶ About 80% of the secretion is epinephrine and 20% is norepinephrine
- ▶ The circulating epinephrine and norepinephrine have the same effect as that caused by direct sympathetic stimulation except that the effects last 5 to 10 times longer
- ▶ Epinephrine causes the same effects as caused by norepinephrine, except that it has greater effect in stimulating the beta receptors and in increasing the metabolic rate (5-10% greater than norepinephrine)
- ▶ The dual mechanism of sympathetic stimulation provides a safety factor, as one of them can substitute for the other
- ▶ Another important value of the adrenal medullae is the capability of epinephrine and norepinephrine to stimulate structures of the body that are not innervated by sympathetic fibers directly

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Sympathetic and Parasympathetic "Tone"

- ▶ Normally, the sympathetic and parasympathetic systems discharge continuously, the basal rates of discharge is known as (tone)
- ▶ The value of tone is that it allows a single nervous system both to increase and to decrease the activity of a stimulated organ
- ▶ Example: sympathetic tone is the blood vessels
- ▶ Example: parasympathetic tone is the gut
- ▶ If the organ is denervated, the tone is lost immediately, but after some time (hours, days or weeks) the tone is restored by development of intrinsic muscle tone
- ▶ The denervated organ become oversensitive to acetylcholine or norepinephrine due to increase receptors number (up regulation)

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- ▶ Sympathetic stimulation occurs in two forms:
 - Discrete local stimulation to one organ without affecting the others
 - Mass discharge leads to stimulation of several organs at the same time called **alarm or stress response**
- ▶ Parasympathetic stimulation is only to discrete organs. No mass discharge
- ▶ **Sympathetic mass discharge (alarm or stress response):**

This also called fight or flight reaction, following emotional stress like fear or rage. This include:

 1. Increased arterial pressure
 2. Increased blood flow to active muscles concurrent with decreased blood flow to organs such as the gastrointestinal tract and the kidneys that are not needed for rapid motor activity
 3. Increased rates of cellular metabolism throughout the body
 4. Increased blood glucose concentration
 5. Increased glycolysis in the liver and in muscle
 6. Increased muscle strength
 7. Increased mental activity
- ▶ The sum of these effects permits a person to perform strenuous physical activity

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Control of autonomic nervous system

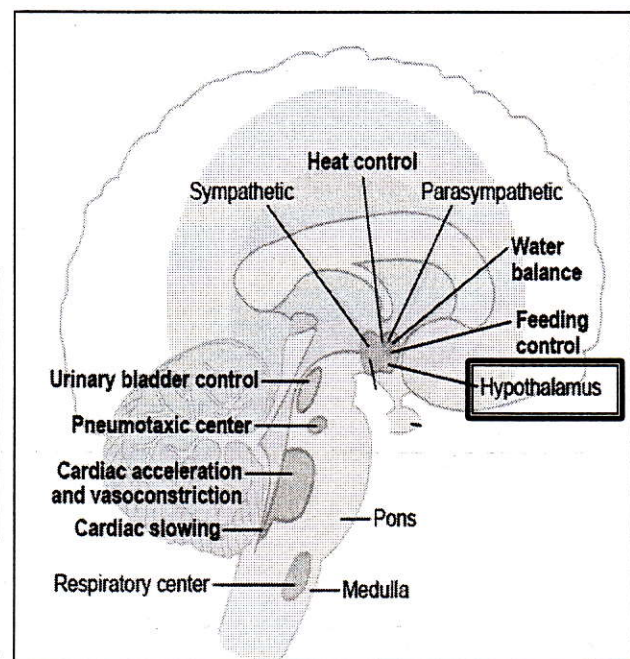
Hypothalamus, cerebral cortex and behavioral centers



Brain stem autonomic centers (most important for: controlling arterial pressure, heart rate, and respiratory rate)



Autonomic nervous system



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- ▶ The hypothalamus is the major controller of autonomic nervous system
- ▶ It has connection with the cerebral cortex, limbic system and pituitary glands
- ▶ Therefore it controls the vegetative and endocrine functions of the body as well as some emotional aspects of behavior
- ▶ Its function includes : - Cardiovascular function
 - Regulation of body temperature
 - Regulation of body water
 - Regulation of feeding behavior
 - Regulation of hormones secretion
 - Participate sleep awake cycle